Industrial QUALITY CONTROL

NOVEMBER, 1954

Vol. XI No. 3

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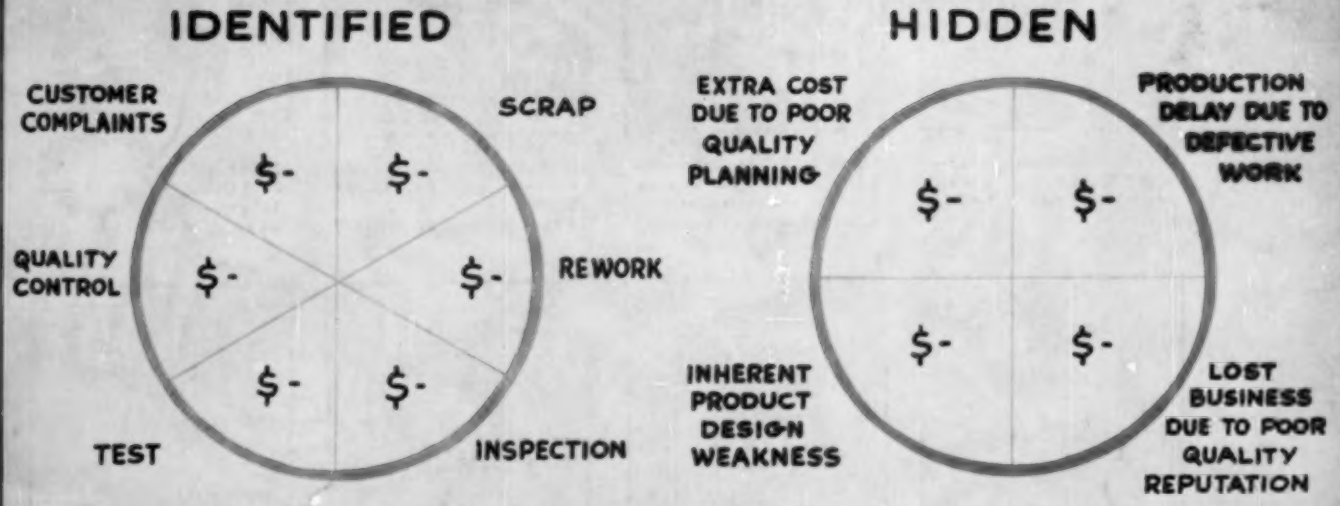

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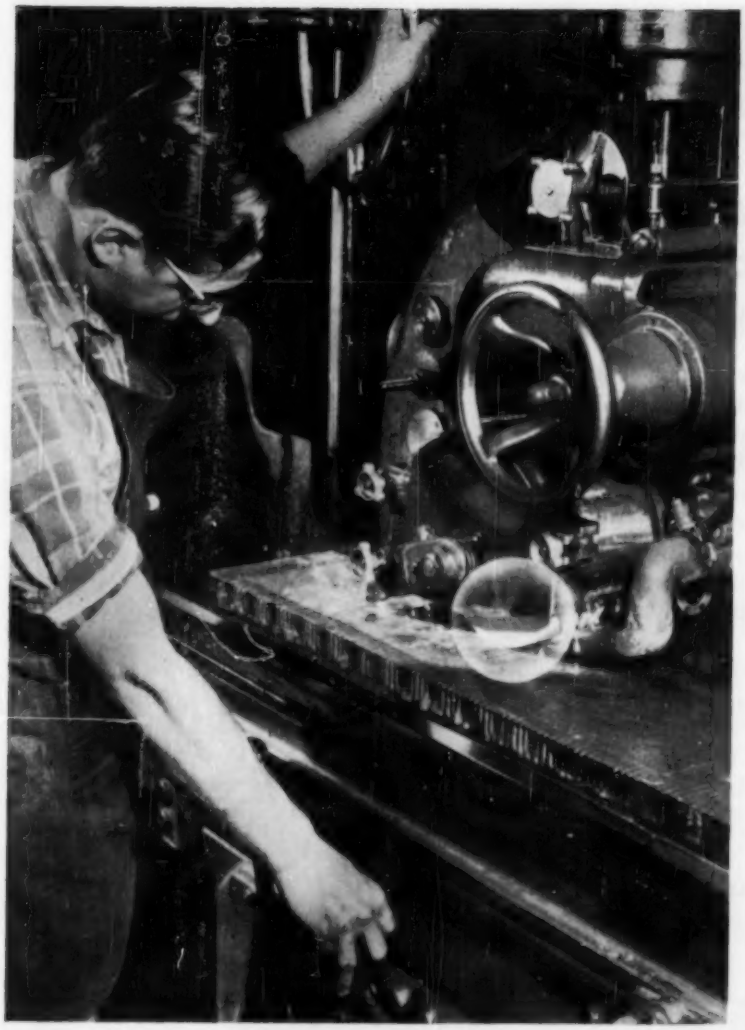

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PAUL CLIFFORD ON LEAVE OF ABSENCE TO EUROPE

It will not come as a surprise to readers of IQC that the usefulness of SQC methods in industry is international in scope. News items have previously appeared in this journal reporting on SQC in India and Japan, and on the several industrial teams that have been sent to the USA in recent years from various European countries to observe and study the operation of these methods in American industry.

Now it can be reported that Paul C. Clifford has been granted a leave of absence from Montclair State Teachers College to serve as consultant on quality control for the OEEC (Organization for European Economic Cooperation.) This project, which is sponsored by the FOA (Foreign Operations Administration), will take Mr. Clifford to Denmark, Germany, Norway, Sweden, Belgium, the Netherlands, France, Italy, and Turkey. The program calls for plant and industry consulting, demonstrations and lectures, and the initiation of training programs. It will require a full year for completion, allowing about one month in each country.

Paul is accompanied on this mission by his wife and family who will reside in Paris while he is out on the assignment, the children continuing their education meanwhile in French schools. The Cliffords left on Sept. 11 and should be back sometime in September 1955. The address through which mail will reach Paul while he is in Europe is:

O.E.E.C.
Chateu de la Muette
2 Rue Andre Pascal
Paris 16, France

During his absence, the Problems Department of IQC, of which Paul is editor, will be in charge of Mr. Thomas A. Budne, Philip Morris & Company, Ltd., Inc., 100 Park Avenue, New York 17, New York. Tom has worked very closely with Paul in the SQC field, and has been active in the service of the Metropolitan section of ASQC for several years. He was also with the team, of which Paul was a member, that went to India in 1952 in the interests of SQC. Our Problems Department is in competent hands under Tom Budne's co-editorship.

Also, the Society is fortunate to have secured the acceptance of Professor Charles R. Hicks of Purdue University to serve on its Editorial Board as an acting member for Paul Clifford during the latter's leave. Professor Hicks' interest, experience, background, and active participation in both theoretical and applied SQC insure that his presence on the Board will provide competent continuity to its responsibilities while Paul Clifford is away.

Industrial Quality Control

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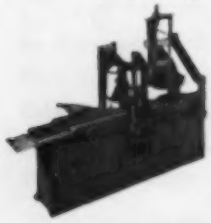

Now Republic has developed an *automatic* coupling inspector for use on Republic seamless couplings made at the new Republic seamless tube mill near Chicago. This new machine automatically inspects all couplings and removes the defective ones.

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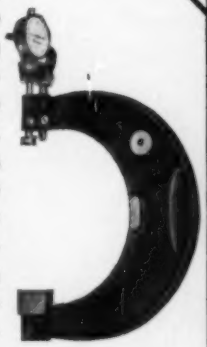

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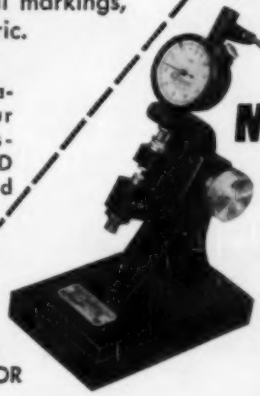

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Methods of Training for QC Engineers and Supervisors

RALPH E. WAREHAM
Quality Control Consultant, Chappaqua, New York

The growth of quality control in industry during the past decade has brought increased need for training key personnel. This training need has been particularly evident in requirements for quality control engineers and supervisors. Even a casual following of newspaper advertisements listing "Positions Open" for quality control engineers and supervisors would show that much training still needs to be done.

When one realizes that ten years ago the total industrial personnel having knowledge of modern quality control methods numbered only a few hundred persons, we can gain an impression of the extensive training that has been done. This training has been carried on in many different ways and through diverse channels. It is not the purpose of this paper to review the training methods used in earlier years, but rather to discuss training methods now available.

Basically, training of quality control engineer or supervisor involves two basic phases:

1. The *educational process* of learning to use modern quality control methods, particularly statistical quality control and acceptance sampling; and
2. The *practical experiences* of applying this knowledge to control of quality of industrial processes and products.

In general, the first step of educational training requires only a limited time, while the second step of practical experience requires a much longer period.

Most of the early quality control engineers and supervisors acquired their training by trial-and-error, in working with factory problems and in studying particular methods applying to these problems. This required a review of available literature on quality control methods, followed by thoughtful consideration as to whether any of these methods would fit the problem at hand. Next a plan for the quality control procedure had to be developed in detail, and reviewed with all interested persons. After usual revisions, the plan would be ready for consideration by the operating personnel of the production unit involved. Acceptance or rejection of the plan was up to the operating personnel. If the plan was accepted, such acceptance was usually qualified and limited; on the other hand, a rejection by operating personnel would mean the end of the proposed plan.

It was on the basis of such trial-and-error methods that the use of average and range charts, per cent defective charts, number of defects charts, process capability studies, cumulative tolerance concepts, and process sampling plans were developed. Scientific applications suggested generalization of quality control methods and techniques. Thus the literature of techniques and of specific applications grew. A good example of such development is found in process capability studies, the techniques for which have been developed within the last few years with new applications reported continuously.

Now the picture regarding the above phases of training quality control engineers and supervisors is completely changed. In the first place, there is an extensive store of literature covering not only quality control principles, but also applications to specific problems in important industries. The recent ASQC Textile Division report on quality control applications and methods in textile operations is an excellent illustration of this development. Furthermore, with public quality control courses and organized quality control departments in leading industrial companies, the opportunities for well-rounded training are extensive. What then are the key steps in securing this well-rounded training?

First, the quality control engineer or supervisor must be adept with the modern tools of quality control, and he must also understand the fundamental relationship of these tools to the industrial processes and products of his plant. For example, the quality control engineer in a chemical plant must understand the chemical processing operations as well as quality control techniques. This requires knowledge of two different types.

Usually a number of individuals may have knowledge of one type—either of quality control or of plant processes. What is essential is the combined knowledge of both phases—and this requires training toward one side or the other for available personnel. For example, a recent college graduate may have taken educational courses in statistical quality control but have little experience in industry or with the industrial processes of his plant; on the other hand, a number of individuals in the plant may have adequate knowledge of plant processes but have no knowledge of quality control methods.

In this situation, the question is frequently asked: "Is it better to give a prospect training in the production process or in the quality control methods?" The answer to this question, of course, depends on the aptitudes of the individuals involved. However, other things being equal, experience indicates that the best course is to train the plant men in quality control methods.

Among the reasons for this statement is the fact that qualified men who understand the process can frequently master quality control techniques with relative ease. Furthermore, their background of plant problems, their familiarity with

plant personnel, their maturity and experience, and their understanding of company objectives enable them to effect practical applications promptly once the methods are learned. This usually means accomplishment of the objective.

Many educational opportunities are now open to plant personnel seeking training in quality control techniques; principal among these are:

1. Evening courses sponsored by extension divisions of colleges and universities;
2. In-plant quality control courses (either during working hours or on an after-hours' basis;
3. Intensive quality control courses on a full-time basis for eight or ten days, held by colleges, by special groups, or by quality control consulting firms.

Each of these methods of training has certain advantages, but the practical side is that good quality control engineers and supervisors have been trained in all of them.

Where plants are located in or near large metropolitan centers, evening classes are usually available. On the other hand, plants located in smaller communities may be directly dependent on in-plant courses (using outside instructors) or on intensive training courses at distant centers. The particular situation of the dividual plant must govern its selection of type of training.

So far, our consideration has been directed to the educational side of quality control training. Once the necessary formal training has been accomplished, the prospective quality control engineer can begin to use his training in practical applications. This is a critical and difficult step. It has been the common experience of many that the gulf between solving class problems and solving plant problems is a wide one. In spite of good intentions and diligent efforts, those assigned to jobs as quality control engineers and supervisors have often failed in technical phases of their jobs due to this difficulty.

The best guidance in carrying class teaching into effective practical application comes from one who has had the experience before. The prospective quality control engineer or supervisor who can work under an experienced quality control manager or quality control consultant can bridge this difficult period with relative ease. Otherwise, an extended period of trial-and-error may be required.

During the period of training in practical applications of quality control methods, the quality control engineer or supervisor needs to meet as many different quality situations as possible. In some companies, this has been accomplished by rotational assignments of quality control engineers to different departments—so as to provide a picture of the full range of quality problems and solutions.

In his work, a newly-assigned quality control engineer will be applying only a small part of his formal knowledge to early quality control studies. This requires that he keep active his interest and knowedge of other methods by continued study and by review of basic methods and techniques. He must keep abreast of the literature by following articles in *Industrial Quality Control* and in industry publications. He must strive to extend his knowledge of advanced quality control methods. He must attend quality control meetings so as to have contact with others in the field.

After instructing in many intensive courses and in college for the last twelve years, I have concluded that each student receiving formal training must supplement the training period with a personal effort to broaden his knowledge and perspective through self-planned study. Key requirement for such personal follow-up are training materials covering a wide range of quality control situations and containing quality control problems for practice. These materials should have been thoroughly studied during the period of original instruction.

The literature of quality control has now become so extensive that the prospective quality control engineer is frequently at loss to know which text materials to use in his personal study program. Use of too many texts or conflicting ones lead to confusion and division of effort. As possible help to those seeking such training materials, the following "kit" is recommended for prospective quality control engineers and supervisors

Statistical Quality Control by E. L. Grant, McGraw-Hill Book Company, New York, 1952

Sampling Inspection Tables by H. F. Dodge and H. G. Romig, John Wiley & Sons, New York, 1944

A.S.T.M. Manual on Quality Control of Materials by American Society for Testing Materials, Philadelphia, 1951

MIL-STD-105A—Sampling Inspection by Attributes, Superintendent of Documents, Washington, 1950

"Statistical Quality Control," *Fortune*, December 1949

Industrial Quality Control published by ASQC.

The above list has been purposely kept short. Later on, the quality control engineer or supervisor could add other valuable text to his working collection.

The three principal traits needed by prospective quality control engineers and supervisors are a good personality, a spirit of inquiry, and adeptness in simple mathematics. The quality control engineer needs a personality that will help him in his contacts with plant operating personnel; he must "sell" quality control ideas every day. He must have a spirit of inquiry so as to seek out reasons behind quality problems in his plant, and so as to assist in finding solutions. Finally, in our Army Ordnance quality control training schools at Frankfort Arsenal, we have found that skill in shop mathematics is a "must" if the quality control engineer is to master statistical quality control techniques.

In many colleges and universities programs of instruction in quality control have grown to the point where many outstanding men are going directly from college into quality control work. This trend promises to continue and even accelerate.

The combination of better educational training and increased industrial experience opportunities has brought important progress in this training field during post-war years. Nevertheless, the broad problem of quality control training remains before industry and will continue to be important for many years.

Cost of Quality

W. H. LESSER

General Electric Company, Schenectady, N. Y.

Sooner or later, every quality control supervisor is called into the general manager's office and asked two questions. "How much does your quality control activity cost?" and "What do I get out of it in terms of increased profit, higher inventory, turnover, cost reduction and improved market position?" Unless he has the financial facts and prompt answers, another quality control program will "bite the dust."

As a comparatively new member of the management team, the quality control supervisor must recognize that his activity is one of many that contributes to manufacturing output and affects profit margin. Management will measure the cost and results of his program and compare his effect upon profit margin with that of other management services, such as: personnel administration or production control. In this paper we shall examine several yardsticks of quality cost that enables management to evaluate the performance of a quality control program.

As is true with most specialized work, it is so easy to spend time on the new and interesting parts of our job, that we sometimes lose sight of our basic responsibility to management, namely—to increase profit. Mr. Paul Hoffman,† past president of the Studebaker Corporation, has said of the responsibilities of business men: "The greatest contribution any business man can make toward stability is to operate his business profitably. Every business man owes this major responsibility to his stockholders, his associates, his workers and the public. Only a profitable business can offer security to its employees."

With the multitude of sales, engineering and manufacturing activities, each clamoring for its share of the budget dollar, the quality control activity must compete on an equal footing by proving simply, and without question, value received for services rendered. An ambitious quality supervisor will sometimes attempt to justify his budget request by statements, such as: "Quality is difficult to measure," or "it is a good idea to spend money on quality control," or "we need more inspection around here." Smart management will seldom accept such unfounded statements, but will listen to statements, such as: "Our cost of quality for 1953 was so many dollars, or "this vendor rating program will increase inventory turnover so many percent," or "operator quality mindedness has improved as shown on this percent defective chart." By making specific statements, and of course being able to justify each one, your general manager will identify your quality activity as paying its own way, and not tag it as a candidate for expense reduction.

Although each industry and manufacturing concern differs in its organization for the control of product quality, there are common yardsticks of quality cost that can be applied to all companies. It is the responsibility of each quality supervisor to establish reliable, but simple, indices of quality cost for each important phase of operation for which he is held accountable. Existing cost reports are usually based upon the traditional classification of accounts, and the quality control engineer must often spend unnecessary time in breaking down product costs into significant, workable form. Accountants must be convinced of the necessity to report quality costs by responsibility, cause, or effect in order to measure the results of corrective action.

Let us now look at the basic elements of quality cost found in any manufacturing organization. Figure 1, the cover picture this month, shows that these quality costs amount to so many dollars a year, and are equivalent to so many cents per dollar of sales.

The more obvious quality costs, or *identified costs*, are

1. Scrap
2. Rework
3. Inspection
4. Test
5. Customer complaint expense due to defective products
6. Quality control costs, including such items as: quality training programs, vendor ratings, product audits, life tests and cost of maintaining statistical analyses and controls.

More difficult to identify are those *hidden costs*, which include

1) Extra costs due to poor quality planning. For example, performing operations on machines incapable of holding the required tolerance, or additional adjust operations needed because of a loosely controlled previous operation.

2) Production and shipping delays due to defective work, occasioned by inspection rejects and the time required to obtain replacement materials.

3) Lost business due to a poor quality reputation among customers. In evaluating this item of cost, care should be used to exclude the lost business caused by price and delivery factors.

*Paper presented on the programs of the Seventh and Eighth Annual Conventions of ASQC, Philadelphia, Pa., May 27, 28, 29, 1953 and St. Louis, Mo., June 9, 10, 11, 1954.

†"The Great Challenge to Capitalism" by Paul G. Hoffman, *New York Times Magazine*, September 8, 1946.

4) Inherent product design weakness, which specifies materials and manufacturing operations unnecessarily difficult or costly to keep under adequate control. Many products are saddled with this type of quality cost until completion of a planned development program, or until model changes can be made in currently manufactured products.

In some companies, the hidden quality costs far exceed identified costs, and educated judgment is required to estimate a reasonable dollar amount. The importance of determining the amount of quality cost cannot be overemphasized, for management should demand a yardstick to measure performance. Many manufacturing organizations now have a good story on the amount and nature of obvious quality costs. Much more work is necessary to pin down those hidden and elusive quality costs in order to fully realize cost reductions from an integrated quality improvement program.

In Fig. 2 we compare the cost of quality with other financial statistics. So many dollars is equivalent to: percent of the output of a contributing department, percent of the expenditures for plant and equipment, percent of wages and salaries paid, and percent of dividends to stockholders. For telling your own company quality story use this kind of comparison, and replace stockholders by profit margin, and the contributing department by your own machine or assembly department, but always compare quality costs with other items of cost familiar to your own general manager. Advertising men often use this comparative sales technique in order to get their customers to evaluate a new and unknown product against the old, familiar brand.

Now let us see where on the financial statements we can find the amount of quality costs. Figure 3 shows extracts from a typical profit and loss statement—the bread and butter report of every product manager. Included in this report are practically all of the costs in which we are interested. Behind each amount shown, there are one or more financial reports which give details comprising the total.

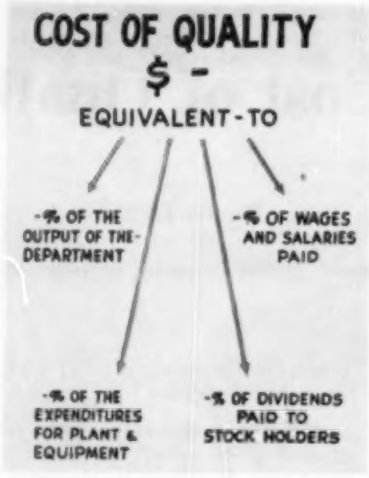
COST OF QUALITY
$ -
EQUIVALENT-TO
-% OF THE OUTPUT OF THE DEPARTMENT
-% OF WAGES AND SALARIES PAID
-% OF THE EXPENDITURES FOR PLANT & EQUIPMENT
-% OF DIVIDENDS PAID TO STOCK HOLDERS

Figure 2

The first item is net sales billed. This is the base upon which most financial ratios are calculated; it represents the income from which a manager must pay for his material, labor, and services, and still have something left over for taxes and profit. The four basic elements of product manufacturing cost are: direct material, direct labor, overhead, and engineering expense. Within these cost elements can be found most of the money upon which a quality control organization can work.

Direct material, often the largest amount of the four items, is always high in priority on the cost reduction budget. In a typical standard cost system of accounting, the direct material account includes: planned standard material, excess spent over standard for delivery, size or quality considerations, and scrap due to poor workmanship, improper planning, or application. A program for improved vendor contacts and certification plans, periodic reviews of specifications and methods with suppliers, adequate incoming material inspection, and internal process controls are typical quality improvement activities. From these activities we expect measurable results in reduced inventory turnover, reduced scrap, and reduced production delays caused by rejected material.

Direct labor consists of planned standard labor, rework, extra cost, as mentioned earlier, and starting costs. An active quality control program can contribute its share to the reduction of non-productive direct labor with the aid of effective process controls, improved job training, publicity campaigns, and the reduction of inspection rejects. The key note in such a program should be to improve the plant wide spirit of "quality mindedness." When fostered by top management and practiced daily by line supervisors, it will be found that a quality minded organization improves the performance and quality of direct labor.

Overhead, sometimes called burden, represents the cost of those services so necessary to successful manufacture, but which do not appear directly in the finished product. This is the one account where heads quickly roll under the axe of expense reduction—it is the place where the cost of supporting a quality control program is measured against services rendered. At this point the quality control supervisor must be prepared to submit his list of cost reductions and his contributions to profit margin in order to justify his own place on the management team.

Some of the overhead accounts which are influenced by a successful quality improvement program are

1) Inspection cost, often reduced by the introduction of sampling plans and control charts.

PROFIT & LOSS STATEMENT

- SOURCES OF QUALITY COSTS

NET SALES BILLED
Less COST OF SALES

DIRECT MATERIAL	STANDARD MATERIAL EXCESS OVER STANDARD • SCRAP •
DIRECT LABOR	STANDARD LABOR REWORK • EXTRA COST • STARTING COST •
OVERHEAD	INSPECTION, QUALITY CONTROL • TRAINING, IDLE TIME PURCHASING, PRODUCTION •
ENGINEERING	PRODUCTION ENGR., LABORATORY TESTS, PILOT RUNS • CUSTOMER COMPLAINTS •

NORMAL GROSS MARGIN
Less COMMERCIAL { CONCESSIONS • CUSTOMERS •
ADMINISTRATIVE
ADVERTISING
ACCOUNTING
NET INCOME BEFORE TAXES
Less: TAXES
NET PROFIT

Figure 3

2) Idle time and high production costs, caused by defective work or weak controls over manufacturing processes.

3) Purchasing efforts expended in obtaining replacement materials.

4) Material handling and stock-keeping charges for handling defective and replacement material.

Engineering expense, including customer complaint cost, is a fertile field for statistical quality control. Planned experiments, statistical analysis of test data, product pilot runs and tolerance analyses can show not only savings in starting cost, but also savings in time when getting a new product on the market. advertising men to the promotion of Considerable attention is given by product quality. This publicity looks good in print, but one must be sure that the outgoing products on the shipping platform are everything the engineers specify and the salesmen claim.

The next chart shows how percent final inspection rejects are translated into dollar cost. Figure 4 shows the amount of money spent on scrap and rework in the assembly of an electrical product. On this monthly chart the upper line indicates percent final inspection rejects. The two lines underneath represent the dollar amount spent on scrap and rework. As can be seen, there was trouble with excessive inspection rejects and high product cost in the first quarter of 1951.

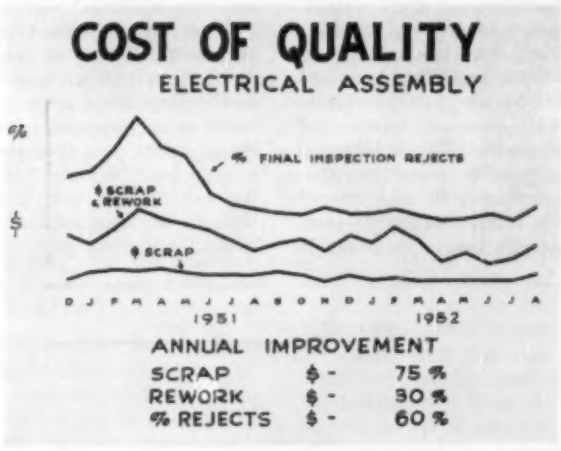
COST OF QUALITY
ELECTRICAL ASSEMBLY
%
% FINAL INSPECTION REJECTS
$
$ SCRAP & REWORK
$ SCRAP
D J F M A M J J A S O N D J F M A M J J A
1951
1952
ANNUAL IMPROVEMENT
SCRAP $ - 75 %
REWORK $ - 30 %
% REJECTS $ - 60 %

Figure 4

At this time a drive was made to arrest the increasing reject trend by a coordinated program to improve product design, tools, assembly methods, and incoming material condition. Note the results of this program as reflected in percent inspection rejects and manufacturing loss reduction. Annual improvement in scrap, 75 percent; in rework, 30 percent; and in rejects, 60 percent. Note how the quality-cost curves travel together. Always express quality control improvements to management in dollars and cents.

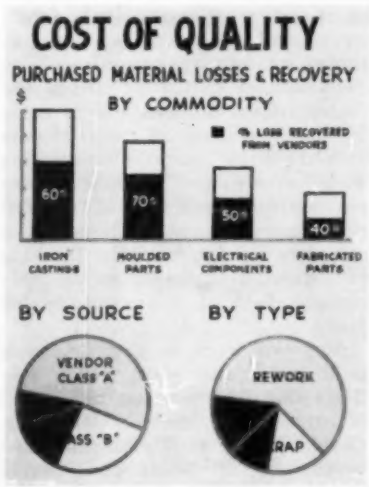

Figure 5

The amount of direct scrap and rework labor caused by defective purchased material is usually easy to obtain from inspection and cost reports, and is a good yardstick to measure the effectiveness of a vendor relations program. Figure 5 gives a breakdown of the amount of incurred loss caused by defective vendor material, and the recovery: by commodity, by source, and by type. The vertical bars represent commodity groups of iron castings, moulded plastic parts, electrical component assemblies, and fabricated parts. Other obvious commodity groups are not shown here. The black area represents percent of incurred loss recovered from vendors due to their defective products. The percent of recovery on commodities such as iron castings is often lower than on plastic moulded parts, because of the lost direct labor in machining castings before hidden defects can be discovered. It is seldom economical to 100 percent test inexpensive, low-strength grey iron castings, and corrective action to reduce losses should be exerted in the direction of good design and foundry practice. Often purchased material losses, as well as total losses, follow a pattern by which a few of the items account for most of the loss. A brief commodity analysis will show which vendors are causing the major part of current troubles. From this analysis we can determine the kind of investigation and corrective action necessary to obtain the desired results.

As the lower left hand pie chart (Fig. 5) indicates, vendors can be classified by source, past performance, or quality rating. This chart shows the percent loss incurred and recovered from "Class A" vendors, as compared to "Class B" vendors. Periodic purchase analyses should be made on supplier's products from the standpoint of design simplification, ease of manufacture with supplier's facilities, materials substitution, and reliability of product quality. Higher recovery is always realized on those vendors selected by the purchasing agent according to the "delivery, price and quality" formula.

The lower right hand pie chart (Fig. 5) shows the proportionate amount of rework and scrap losses incurred, and percent recovery for each type. Note a higher recovery on scrap than on rework. This is usually true because of the continual squeeze on the user to repair immediately defective material in

order to maintain product output. Under pressure of meeting production schedules, the real nature and cause of defects are often lost, and it is difficult to adequately impress vendors with the seriousness of their faulty quality. This is where a progressive vendor relations program will save money and reduce inventory by halting defective purchased materials before shipment is made to the user.

Your key elements of quality cost can be presented to your management in a similar manner. Charts and dollars go a long way to convince your manager that the quality program is self-supporting, but always bear in mind that the quality yardstick is only one of many used by top management to measure overall company performance. The keen quality supervisor displays good business sense to compare his cost objectives with those of other services also competing for budget dollars. It is only after we display a knowledge of the facts upon which we will be measured for performance, that we can expect the general manager to support wholeheartedly our quality control program.

A Trade Unionist Looks At Quality Control

WILLIAM GOMBERG

Int'l Ladies' Garment Workers Union, AFL

A trade unionist's interest in quality control combines the general curiosity of the average scientifically minded citizen in advancing technological progress with a specific interest in its impact on the employer-employee relationship.

Modern statistical quality control techniques impinge upon the employer-employee relationship along the following lines:

1. Statistical quality control introduces another factor of technological change threatening the stability of historical job requirements and relationships in specific industries.

2. Statistical quality control has been offered as one of the criteria in developing standards of performance under otherwise orthodox time wage payment plans or incentive wage payment plans.

3. Statistical quality control has, to an unprecedented degree, popularized the application of sound statistical theory to hitherto empirical methods of deriving standards of production and expected worker performance.

Let us start first with a discussion of quality control as a factor of technological change. The introduction of statistical quality control has meant a reduction in the number of inspection jobs for workers for a given unit of production. The problems presented to the trade unionist have been less difficult to handle, if anything, than the vast displacement in historical job relationship caused by more dynamic and drastic sources of technological change. The The U. S. trade unions have developed a set of protective devices and a code of industrial jurisprudence to cope with these developments. They are designed to encourage a maximum of free technological development in our society and simultaneously protect the interest of the workers affected. In civilized communities today we have ceased to use the bromide—"you can't stop progress" to conceal the assumption that the workers must bear the entire brunt of hardships that normally must arise in a dynamic expanding society. I hardly think that this is the place to examine these codes and practices closely; there is vast literature on the subject to which reference may be made.

Let us therefore proceed to point number two. A set of expected worker performance underlies most wage incentive payment plans. The measurement of this performance is made up of two dimensions—quantity of performance and quality of performance. Specifically it answers questions like how many rejects can be expected from a worker before he personally can be held responsible to be an "assignable cause of variation" in the manufacture of some specific product. The application of this thinking to the development of wage incentive payment plans is routine and does not justify extensive development at this time.

The most dramatic contribution of statistical quality control to industrial relations has been in establishing the philosophy basic to a scientific criterion for the establishment of production standards. Quality control, or better yet, the statistical philosophy promulgated by Shewhart in industrial circles has destroyed the fantastic claims made for magic systems of standard data erected by pseudo-investigators whose avowed good intentions were no match for their lack of technical competence. It is at the bottom of a complete revolution in the thinking of industrial engineers in the specialized field of time and motion study.

My own work in this field was published some eight years ago. Since that time scholars like Adam Abruzzi of Columbia University, Gerald Nadler of Washington University of St. Louis and Harold Davidson of Ohio State University have developed the field far beyond

the boundaries I had staked out at that time. Very few contributions have been as important as these approaches for the labor movement in developing an attitude toward the proper application of time study techniques to collective bargaining.

It would be fruitful at this time to review some of the thinking that entered into the formulation of a statistical approach to time study. There had been virtually no departure from the original principles of Taylor in developing time study techniques up to the time of the challenge of the statisticians.

Practically every other scientific field honors its pioneers for their heroic explorations into the realms of the unknown. Most of their findings it is understood have been made obsolete by the investigations of subsequent scholars. Moreover, time study resembles theology much more than it does a scientific methodology. Taylor and Gilbreth are deified rather than honored and the contest among time study practitioners seems to be who can claim the greatest orthodoxy rather than the greatest validity.

The elementary principles set down by Taylor in the early 1900's follow:

a. Divide the work of a man performing any job into simple elementary movements.

b. Pick out all useless movements and discard them.

c. Study, one after another, just how each of several skilled workmen makes each elementary movement, and with the aid of a stop watch select the quickest and best method of making each elementary movement known in the trade.

d. Describe, record and index each elementary movement, with its proper time, so that it can be quickly found.

e. Study and record the percentage which must be added to the actual working time of a good workman to cover unavoidable delays, interruptions, and minor accidents, etc.

f. Study and record the percentage which must be added to cover the newness of a good workman to a job, the first few times that he does it. (This percentage is quite large on jobs made up of a large number of different elements composing a long sequence infrequently repeated. This factor grows smaller, however, as the work consists of a smaller number of different elements in a sequence that is more frequently repeated.

g. Study and record the percentage of time that must be allowed for rest, and the intervals at which the rest must be taken, in order to offset physical fatigue.

h. Add together into various groups such combinations of elementary movements as are frequently used in the same sequence in the trade, and record and index these groups so that they can be readily found.

i. From these several records, it is comparatively easy to select the proper series of motions which should be used by a workman in making any particular article, and by summing up the times of these movements, and adding proper percentage allowances, to find the proper time for doing almost any class of work.

j. The analysis of a piece of work into its elements almost always reveals the fact that many of the conditions surrounding and accompanying the work are defective; for instance, that improper tools are used, that the machines used in connection with it need perfecting, that the sanitary conditions are bad, etc. And knowledge so obtained leads frequently to constructive work of a high order, to the standardization of tools and conditions, to the invention of superior methods and machines.

A glance over the ten steps reveals the subtle acceptance of a purely mechanical view of nature. Here the substance, the mechanical concepts with which science had been made to work in the field of nineteenth-century physics, was artificially transplanted into the field of time study techniques. The fact that the only claim that could be made for these assumptions was that they were subject to tests of validity by the scientific method was confused with the superficial resemblance between the directions to divide a man's work into simple elementary motions and the appearance of the atomic and molecular theory of physical science. Taylor's paragraph "i," that the best elements be combined into a synthetic pattern arithmetically, completely overlooks the possibility that these atomic movements might combine—as hydrogen and oxygen do—to form a completely new compound—water—bearing little or no resemblance to the original constituents from which it was formed, rather than make up an additive set.

Shewhart's concepts were used to challenge this system of thinking. They were used to point out that the development of scientific production standards must depend upon the derivation of a sound statistical sample from a distribution of work times. These work times if they are to yield a sound, meaningful, statistical sample must, in turn, come from a statistically stable parent population.

It is axiomatic that a statistically stable population must be free of any dominant assignable cause of variation. The working environment making up the surroundings within which the worker uses his tools is subject to so many disturbances that it is well-nigh impossible to list them, much less isolate their individual effects. These variations may be classified as follows:

1. The purely mechanical
2. The psychological
3. The physiological
4. The sociological

The wage system and method of wage payment would fall into category four—that is, the sociological. It perhaps is the most dominant influence in this category influencing the amount of work that can be expected. It is therefore sheer nonsense to talk about measuring a fair day's work independently of the wages or wage system.

The fruitful application of quality control philosophy is perhaps best illustrated by three time study questions proposed by Adam Abruzzi:

1. What are the criteria which may be used to determine that a process is standardized and ready for a time study?

2. What constitute meaningful summarizing statistics of time study data?

3. How valid are current standard data procedures?

The philosophy of Abruzzi's approach to the analysis of time study data may be summarized as follows: "Subjective procedures of rating current productive rates to predict the time of a theoretical normal worker has no function in an objective methodology."

This of course means two things in terms of union policy:

1. Subjective rating procedures are rejected as objective determinants of a so-called scientific production standard in collective bargaining.

2. So-called scientific studies such as the rating project conducted under the auspices of the Society for the Advancement of Management are rejected. The distribution of the subjective prejudices of the industrial engineers of America about what they would like to be a normal working speed is an interesting game but hardly a serious objective investigation.

Let us now talk about standardization of the job. When is the job ready for a time study? An examination of the literature discloses qualitative descriptions that vary from one extreme to another. One authority demands virtually the performance of a micromotion pattern that satisfies the micromotionist's concept of the most economical combination of elemental motions. Others, like Carrel, are all for taking the study on the job just as it is found. They feel that the job pattern can never satisfy the demands of the perfectionists and tend to the other extreme.

Abruzzi departs from these qualitative descriptions and merely asks one question: Do the performance times of the workers satisfy some rational operational criteria of statistical stability? He has defined this stability on two levels, local stability and grand stability. Local statistical stability is measured in terms of the variation in production times over a continuous series of items made over a few hours or at most a continuous day. Grand statistical stability is measured in terms of the variation in production rates of a series of small samples taken over an extended time interval from increments considered qualitatively to be taken under essentially the same conditions.

The criteria for local stability consisted of building up Shewhart control charts for the means and ranges from as many as 70 subsamples, consisting of three items each, from a total of 210 continuous readings on a single individual. This was done for individual elements as well as overall cycles.

In addition, Abruzzi has introduced a new criterion of stability, the mean square successive difference ratio, test, viz

$$\frac{\delta^2}{s^2} = \frac{\sum_{i=1}^{N-1} (X_{i+1} - X_i)^2/(N-1)}{\sum_{i=1}^{N} (X_i - \bar{X})^2/(N-1)}$$

where

X_i = Any individual reading $(i = 1, 2, \ldots N)$

N = Number of observations

Significantly small ratios indicate that successive observations are positively correlated; significantly large values indicate that successive observations are negatively correlated. Thus this statistic becomes valuable to detect any trends in the data. The same methods used to determine local stability were in turn used to detect grand stability except that in this case the collection of data took place in very much the same manner that data collection for ratio delay studies takes place. Random readings in continuous series of five items were taken. They were distributed during the four basic work periods of the day. Again, these tests disclosed the existence of grand statistical stability.

The disclosure of the existence of this grand stability does prove that scientific time study is possible. That is, time study which is performed in accordance with the requirements of sound statistical inference. However, what remains to be disclosed is whether or not the limits of variation for both means and ranges are so wide that the results are of little economic significance for setting production standards. Abruzzi concludes from his findings that control charts with 3-σ limits for groups of workers show equal degrees of variability even though they show widely different mean unit rates of productivity. The most important finding, however, is that local stability does not necessarily imply the existence of grand stability. They are two independent entities.

Inasmuch as trade unions are interested in the long term characteristics of earning opportunities it follows at once that they are much more interested in the conclusions derived from grand stability rather than from local stability. This, of course, means a change in the conventional method of collecting time study data. Where before a continuous short run study was considered adequate, now small runs of five readings taken at random intervals over an adequate period yield more adequate data.

The next question which we wish to examine is how valid is current standard data practice. Abruzzi examines both the macroscopic type of data and the microscopic data. In the course of his examination of microscopic data he describes the fundamental fallacies of the validity test proposed by Maynard, Schwab and Stegmerton for methods time measurement. I have published this analysis in my review of their book for the Cornell Industrial Relations Review and there is little point in repeating the conclusions here.

Abruzzi's principal contribution to this field arises from his examina- of what constitutes a logical subdivision of a total work cycle into elements. His statistical analysis was designed to determine whether or not the usual subdivisions of cycles from the most macroscopic to the most microscopic were statistically independent. These elements would have to be statistically independent if they are to be used as an *additive* set; that is if they are to carry a time assignment independent of the element that precedes or follows the element being measured. If statistical independence cannot be established for these elements then a minimum condition for their use must be at least a constant relationship or correlation. By the use of rather complex statistical multivariate analysis techniques, Abruzzi found that for some specific operations the nature of the relationship among macroscopic elements, let alone microscopic elements, was so complex that it varied from operator to operator. In fact, at times it varied at different times for the same operator. (These findings were subsequently confirmed independently by Prof. Gerald Nadler of Washington University, St. Louis, Missouri.) This is hardly the sort of foundation upon which objective

systems of microscopic data can be built. These conclusions would tend to substantiate the findings of the gestalt psychologist and industrial engineers like Gillespie and Mundel. "The whole is greater than the sum of its parts."

Does this mean that trade unions will reject all systems of standard data out of hand? Not at all. We are willing to recognize that they are a rather poor empirical attempt to develop a *modus vivendi* upon which both management and labor can reach agreement. However, under no circumstances would we permit ourselves to be bound solely by the technology of these systems in dispute cases. They at best stabilize a human relationship. They are useful provided we recognize that the failure to achieve a rate developed under standard data does not indict the worker; the rate may very well point up the limitations of the technique.

If the philosophy of the quality control technique did nothing else for the labor movement except undermine the nonsensical foundation of fads, like methods time measurement, that in itself would have made it a major contribution to stable relationships between employers and labor.

Some Quality Control Applications In The Aluminum Company of America*

W. P. GOEPFERT

Aluminum Company of America, Pittsburgh, Pa.

ANY quality control program should have as its goal the production of a product or the performance of a service to the satisfaction of the consumer at a minimum cost. The term "consumer" in this statement is to be considered in the very broad sense of including any other department of the same producing or servicing company or a subsequent operation within the same department as well as the customer for a finished product.

During both the recent Korean conflict and World War II, there was too often a tendency for the free use of the statement that "cost is not a factor." The same circumstances that led to the use of this expression, however, were the causes that prompted the imposition of government allocations and controls of various sorts with the objective of conserving materials, machines and manpower and directing their utilization for assigned purposes. It must be realized that materials, machines and manpower are costs, with particular emphasis on manpower. Costs, therefore, should become an even more important consideration in times of high production for defense purposes than under normal peace time operations.

In normal times, industry is extremely conscious of costs and customer satisfaction in the interest of survival under competitive conditions. During war times, as preparedness programs are developed and industry is geared to military production, it is in the interests of national welfare, to produce products to the quality standards suitable for the intended purpose at a minimum cost. Only by such effort can raw materials, machines and manpower be economically utilized. Thus during either a wartime or normal economy, quality control departments are in a position to offer major assistance to these ends.

DETERMINING DESIRED QUALITY LEVEL

To economically supply the quality required for a particular application, it is basically sound that an accurate knowledge of that required quality be known by the producer. As in most industries, the aluminum industry has for its products certain characteristics which are considered standard. For characteristics such as mechanical properties and dimensional tolerances, these standard qualities are formalized in published tables appearing in sales literature and commercial specifications. Other characteristics such as surface finish, degree of porosity in cast products, degree of freedom from stains, etc. do not lend themselves so readily to positive description but, nevertheless, have a certain accepted level of quality in standard products. The maintenance of these standard quality levels requires expenditure of effort in processing, inspection and reworking. Additional operations are often necessary to provide this standard quality.

For example, the production of standard straightness in an extruded product requires a straightening operation. If the degree of straightness described by standard tolerances is not important in the end use of the extrusion, it might be possible to satisfy the straightness requirement of the customer without expending so much time and effort in the straightening operation. At the same time, if ductility is an important factor in subsequent operations by the customer, it will be to his benefit if the extrusion is not given

*Paper presented on the program of the Fifth Annual Convention, ASQC, Cleveland, Ohio, May 1951.

further cold work such as would be induced if further straightening operations were performed. Unless the facts are known to the producer, considerable time and effort might be wasted in building into a product a quality characteristic that is not significant to the consumer and at the same time lowering the level of a characteristic that is of importance.

Visualizing the possibility of being of greater true service to its customers, if more detailed information were available on the end use to which its products were to be put, Aluminum Company of America created a system known as Quality Requirement and Special Practice Records. This system was put into operation in 1946 to assist us in efficiently fulfilling the quality needs of those customers for whom all the standard characteristics of a given product are not required for their application and/or for whom certain characteristics are desired at a quality level higher than the standard.

It is not intended here to go into the details of the operation of this system but rather to describe this tool of quality control.

A Quality Requirement Record is a compilation of significant information concerning the use to which the customer will put the product described therein, the characteristics of importance both from the point of view of the customer's fabricating procedures and from the acceptability of the finished product, and other information useful as a guide in supplying a product suitable for the intended purpose. Figure 1 is a Quality Requirement Record form for sheet products. Scanning this form from top to bottom, it will be noted that first, provisions are made for complete information as to Record number, customer, Alcoa product and end product. Following this information, a check list is given for the characteristics which might be retained the same as present in the supplied stock and the nature of the service the finished part is expected to perform. Continuing down the form, attention is directed to the operations which the customer will perform on the material and farther down to the quality factors that are important to the customer in the material as supplied.

There can be established on this form a definite idea of the quality requirements of the customer for sheet material to be used in manufacture of his end product. This information is made available to all the plants of Alcoa that might be called upon to furnish material for this application for this customer. On all subsequent similar orders from the customer for this application, reference will be made to the assigned Quality Requirement Record number. Thus these desired quality requirements are impressed on the minds of operating supervision each time an order for this application is received, regardless of the plant to which the particular order might be allotted.

QUALITY REQUIREMENT RECORD
Sheet Products

Date Issued_____ Record No._____

Alcoa Product_____ Customer_____

End Product_____ Address_____

Order No._____ Item No._____ Date Order Entry_____

Description of Alcoa Product:

USE INFORMATION

End product will retain original - Thickness ☐ Length ☐ Finish ☐
Width ☐ Diameter ☐

Chief Use: Structural ☐ Ornamental ☐ Utility ☐

Customer will perform following operations:

Cutting		Working		Joining		Finishing	
Blank	☐	Bend	☐	Braze	☐	Anodize	☐
Machine	☐	Brake Form	☐	Weld		Clean	
Rout	☐	Press Form	☐	Spot	☐	Etch-Acid	☐
Saw	☐	Draw	☐	Butt	☐	Etch-Caustic	☐
Shear	☐	Forge	☐	Torch	☐	Paint	☐
Slit	☐	Roll Form	☐	Rivet	☐	Polish	☐
_____	☐	Spin	☐	_____	☐	Scratch Brush	☐
_____	☐	_____	☐	_____	☐	Finish only One Side	☐

Important quality factors for product as supplied:

Measurable		Metallurgical		Visible	
Diameter	☐	Deep Drawing	☐	Flatness	☐
Length	☐	Freedom from Bars	☐	Freedom from Oil	☐
Squareness	☐	Workability	☐	Freedom from Oil Stains	☐
Straightness	☐	_____	☐	Brightness	☐
Thickness	☐	_____	☐	Smoothness of Edges	☐
Width	☐			Uniform Appearance	☐
_____	☐			Smoothness of Surface	☐

Require only One Good Side ☐ Identify Good Side ☐

Remarks:

Data Supplied by_____

7-24-46 Drawing Attached ☐ Remarks on Opposite Side ☐

Figure 1

SPECIAL PRACTICE RECORD

DATE ISSUED_____ RECORD NO. _____

ALCOA PRODUCT_____ CUSTOMER _____

END PRODUCT _____ ADDRESS _____

Order No._____ Item No._____ Date Order Entry _____

Description of Alcoa Product

Purpose and Details of Special Practice

Copy No. Data Supplied By_____

Figure 2

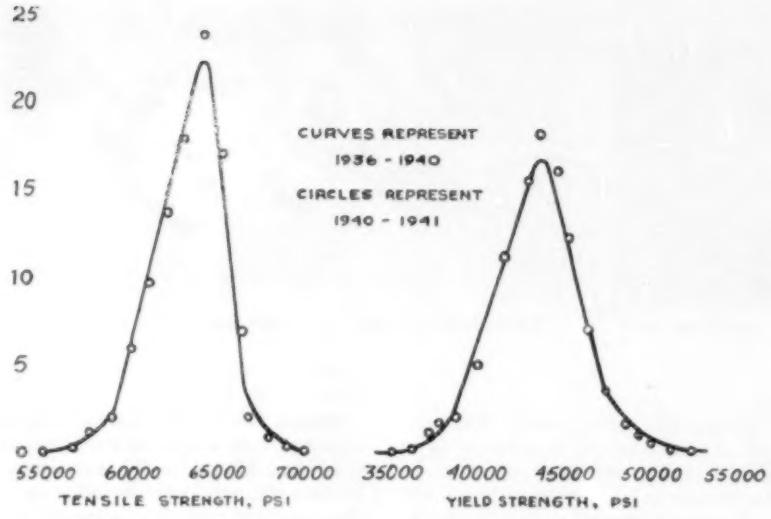

Figure 3

In the event that the production of the quality standard outlined in a Quality Requirement Record requires any special processing procedures, the practices to be used are outlined on a complementary form. The form designed for this purpose is called Special Practice Record and is shown in Fig. 2.

It will be noted that this form is arranged so that it is identifiable with the applicable Quality Requirement Record and has space provided for outlining the detailed procedures to be followed. As with the Quality Requirement Record, copies of the Special Practice Records are distributed to all Alcoa plants which might fabricate this item so that the same proven procedures will be followed to produce the product to the customer's satisfaction in the most economical manner. Consider the value of the records provided by this system in the event that the use of aluminum should be curtailed in a large number of the applications covered by Quality Requirement and Special Practice Records for an extended period of time as a result of government allocations. At the time of resumption of normal availability, these records will be ready reference on the "know how" of satisfying the quality needs for the respective applications and should help expedite the efficient change over to production for these normal usages.

CONTROLLING PROCESSES

One method for fulfilling a primary requisite for a successful quality control program, i.e. establishment of the required quality level, has just been described. Two other requisites of primary importance may be classified as process controls and acceptance inspection. Of these two, process controls currently seem to be obtaining the greatest attention as a result of the emphasis that has been put on the necessity of building quality into the product as opposed to the older ideas of inspecting out bad quality.

For many years Alcoa has had the philosophy of process control and fortunately, therefore, has not had to adjust its thinking too drastically to adopt the current procedures of statistical quality control. Some of our ideas of the mechanics of process control have certainly changed with the advent of the Shewhart control chart and these newer tools of process control have been found extremely useful.

We have utilized for many years frequency distributions and the theory of the normal curve in establishing guaranteed mechanical properties for our products. It is our practice in introducing a new product to accumulate mechanical property test data sufficient to give a fairly complete frequency distribution. These distributions are then used as the basis for selecting minimum and/or maximum values to which the product under consideration can be controlled. As time goes on, frequencies for later production are compared with the older data to determine if any significant shift has taken place.

Figure 3 is a typical plotting of tensile ultimate and yield strengths used for this purpose. The solid curves represent accumulated test results for the period 1936-40. As a basis of comparison, test results on some forty odd thousand tests made on production of this product during the year of 1940-41 have been superimposed on these curves as open circles. It is interesting to note how well this production coincides with that of previous years with regard to mechanical property distributions.

The previous example indicates that we have been using statistical approaches to our problems for some long time, as have a large number of other industrial organizations. In recent years, however, with the further development of modern methods of quality control, attention has been focused a little more definitely on the benefits obtainable by application of statistical methods to the control and inspection of quality of aluminum products.

The specific applications described in the following sections have been selected with the intent of presenting a varied coverage of some of the products of Alcoa manufacture.

The Stockbridge Damper

A survey of shipments for the year 1950 broken down to consumer industries showed that about 19 percent of Alcoa's products went into building industry, 18 percent into transportation, 8 percent into power transmission conductors, 8 percent into household appliances, 6 percent into cooking utensils, 4 percent into machinery and the remainder to other uses. Although the above shows that a large percentage of aluminum products go into the building and transportation industries, a fairly good portion is used in power transmission lines. For these long spans of transmission lines, Alcoa supplies in addition to cable, numerous accessories that play an important part in the successful life of such lines. Two such accessory items are the Stockbridge Damper and Tapered Armor Rods.

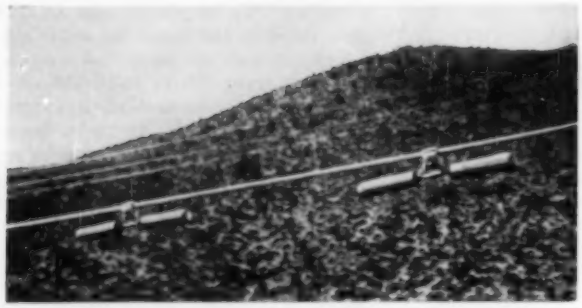

Figure 4—The Stockbridge damper in use on transmission line.

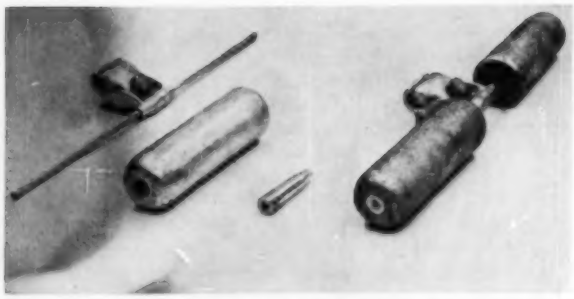

Figure 5—The Stockbridge damper components and assembly.

Encouraging success has been experienced in the application of control charts to the production control of these items. The Stockbridge Damper is shown as used on a transmission line in Fig. 4. Its purpose, as indicated by its name, is to damp out vibration of the line and thus reduce the liability of fatigue failure. Figure 5 shows the components of a Stockbridge Damper and the assembly.

The collet in the center of this picture is used to attach the weights securely to either end of the resilient member or length of cable shown at the extreme left. The primary taper of this collet and the taper of the hole in the weight are of utmost importance if the weights are to be held securely in the assembly. It is a serious matter to have these weights dropping off an overhead cable after they have been in service. The weights on a damper of size commonly used, for example, weigh seven pounds each. In addition, the fit of the collet and weight must be such as to minimize projection of the end of the collet beyond the end of the weight. Such projection can result in corona effects which are undesirable because of their interference with radio reception.

Figure 6 is a typical control chart used on the taper of one size of collet for such an assembly. The measurement made is that of the height of projection of the collet from a special taper gage designed for this application. Particular attention is invited to the improvement effected in the variability of this characteristic as shown by the narrowing of the range chart. The early data were plotted away from the machine and later the charts were explained to the machinist who became interested and successfully endeavored to improve his performance. The improvement made here entirely as a result of the increased operator interest has considerably reduced the difficulties previously experienced in the assembly operation and improved the overall efficiency of the assembly. Similar controls are being used on the taper of the counterpart hole in the weights.

Tapered Armor Rods

Armor rods are used at points of support of transmission lines to prevent abrasion of the conductors at such locations and to decrease the bending stress resulting from vibration. They also perform a secondary function in damping out vibration and protecting the cable from flashover burns. Tapered armor rods are lengths of aluminum rod machined to a given taper calculated to be most efficient in performing the function of blending the nest of rods with the cable.

Figure 7 shows tapered armor rods as installed on a transmission line. In addition to the importance of proper taper in the functioning of the rods, it can readily be recognized that the ease of clamping such assembly, especially when working on a hot line as is sometimes necessary, is important and is contingent on a properly nested condition at the juncture of the rods and the cable. The effort made in studying and subsequently controlling the operation of machine tapering rods of this type has been well repaid.

In the early part of 1950, considerable difficulty was being experienced in maintaining desired consistency of taper on these machine tapered rods. With the hope of rectifying this situation, a program was introduced to study the capabilities of producing a more uniform taper.

It was decided first to establish an additional tolerance to be held at a location 2 in. from the ends of the

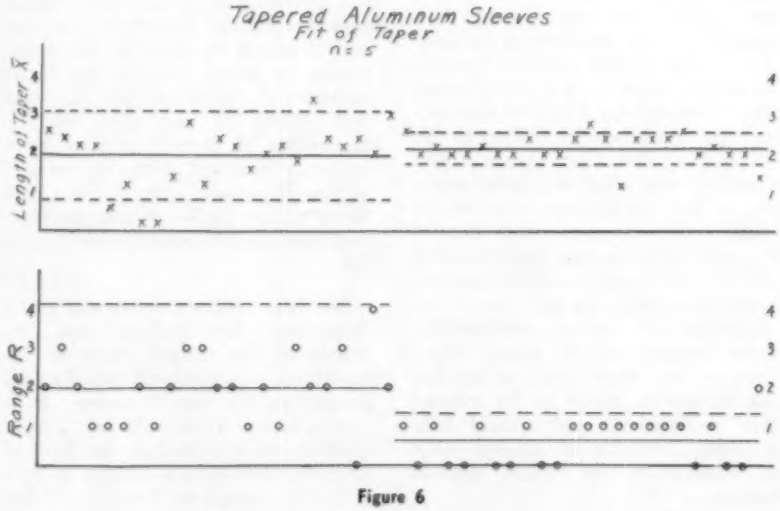

Figure 6

rods to supplement existing tolerances. This location was selected because it is here that the clamps are normally applied and difficulty in assembly was being experienced. An attempt was then made to hold this new tolerance in production but the results were not encouraging. Even after the tapering machines were overhauled it was found that excessive scrap and a dropped production rate resulted from attempting to maintain the tolerance at the 2-in. location.

It was then decided to try the use of control charts on the operation. Five samples from each lathe were taken each hour and $\overline{X}$ and R charts plotted for the diameter 2 in. in from each end of the rods. Different charts were plotted for each size of rod produced on each machine. There being seven machines, as many as 14 charts were maintained at one time and in covering all the sizes, the complete task involved keeping a total of 280 charts.

Without going into the detailed step-by-step accomplishments effected with the aid of these charts, the story on this item can be concluded with the statement that production on this operation was increased, scrap was decreased and cost was lowered. At the same time an improved product was being produced because of the closer tolerances being maintained. The charts were effective in this operation because of their psychological effect on the lathe operators, as well as their usefulness in predicting need for adjustment or maintenance. In the latter case, they thereby provide a basis for more efficient scheduling of repairs so as to reduce to a minimum the interference with production.

Collapsible Tubes

One of the more interesting fabricating processes performed on aluminum is that of impact extrusion. In this process a slug of metal is seated in a die and a punch made to strike it with an impact load causing the metal to literally squirt up around the periphery of the punch to form a can or tube shape. It is by this method that collapsible tubes are made for diversified applications including containers for tooth paste, shaving cream, pharmaceutical products, etc.

Control charts have aided in dimensional control of such operations. In the interest of satisfying a request for closer than commercial tolerance, it was agreed that a study would be made of the practicability of holding the desired tolerance on the average wall thickness in the area from the open end of the tube inward for a distance of 1 in.

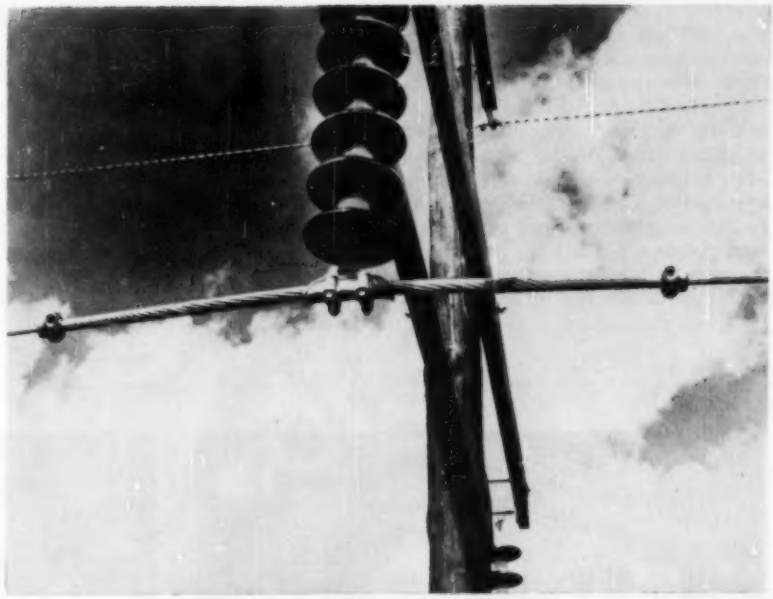

Figure 7—Use of the tapered armor rods on a transmission line.

Figure 8 shows the improvement effected in this case. The first section of the chart represents preliminary data accumulated under normal production of this part to commercial standard tolerances. The set-up man on this machine was then told to do the best he could to maintain the closer tolerance and was instructed to a very limited extent concerning the control charts which were being maintained as a running record of the dimensional control being obtained.

The latter section of this chart shows the $\overline{X}$, R charting of the average wall thickness for a period thereafter. The control limits are

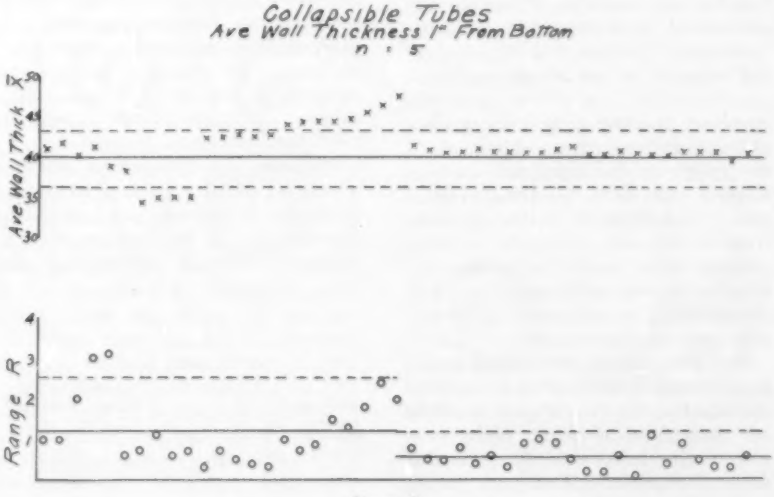

Figure 8

modified limits within which averages of five must fall to indicate conformance with the desired tolerance. Measurements on this application are made with an air gage and the value for each tube is taken as the average of the highest and lowest value obtained in scanning the area to be controlled. This job is run intermittently as orders are received and it has been possible to maintain equally good control on each production run as is exhibited by this chart.

Figure 9

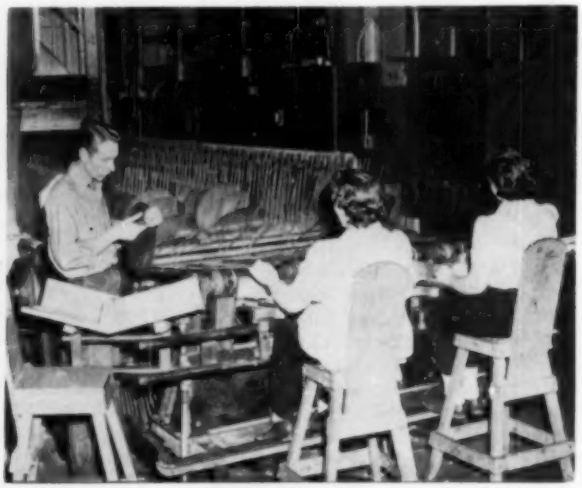

Figure 10

Permanent Mold Piston

Another aluminum alloy item of popular acquaintance is the permanent-mold automotive piston. Large quantities of these are supplied to the industry in the rough machined condition. In view of the quantities involved and the numerous dimensional requirements on this product, the rough machining operation was singled out as a possible fruitful place to apply some modern process control methods. With the characteristics to be controlled in the machining operation being primarily dimensional, a program of control charting was instituted.

However, although useful information was developed as a result of maintaining charts on each machine for each type of piston being produced, the burden of this charting seemed excessive. For each piston, such dimensions as outside diameter, head thickness and squareness, concentricity, inside diameter at skirt end, pin hole to head distance, etc. had to be maintained within certain tolerances. The number of charts required for these dimensions multiplied by the number of machines and the number of different types of pistons supplied was considered prohibitive. With the background of this charting experience, however, it was decided that good control could be effected by use of an attribute sampling plan.

An inspection plan was set up on the basis of relatively small lot sizes consisting of consecutive production from a given machine. Inspection is conducted on the machine line floor as soon the number of pistons comprising the lot has been machined. Tabulations of failure to meet the individual dimensional requirements are maintained and the failure of any lot to pass the sampling plan is immediately brought to the attention of the foreman or set-up man. Details concerning the nonconforming dimension are furnished to assist in determining what corrective action should be taken. Acceptable and rejectable lots are tagged accordingly with the result that no further inspection for dimensions is required of the acceptable lots, but rejectable lots are detailed in final inspection for the particular dimension found outside of tolerance under the sampling plan.

This plan has proved to be efficient from an inspection cost viewpoint but even more outstanding because of its influence in reducing the number of off tolerance pistons produced at the machine. Table I gives a tabulation of the monthly machining process average estimated from the sample results for a period of time after installation of this in-process sampling inspection. Distinction is not made in this tabulation between reworkable items and scrap items.

Table I

Month	% Rejectable (Outside Tolerance)
January	8.7
February	9.0
March	8.0
April	4.8
May	4.6
June	2.5
July	2.3

ACCEPTANCE SAMPLING FOR CONTROLLING PROCESSES

For processes in which data have shown a rather well established variability of a given characteristic to exist, efficient inspection by variables plans can be easily developed. A paper by Dr. Edwin G. Olds* in-

*Edwin G. Olds, *Acceptance Sampling By Variables*, ASQC Conference Papers, 1947.

cited the investigation and use of this type of approach in the inspection of hardness of certain classes of aluminum alloy forgings. The details of this type of plan are available in the reference. In general, the plan provides that the values obtained in inspecting the required sample be averaged and that the decision to accept or reject for detailing be based on the relationship of the average obtained to that of a statistically calculated value derived from the guarantee and the accepted risks. It is highly desirable that a range or standard deviation chart be kept concurrently on the test results as a check on the continued operation within the standard deviation on which the plan is calculated.

It is the opinion of the author that the psychological effect on the Inspector of the necessity of his recording and using his individual readings in this manner to make a decision is all in favor of his being more careful and precise in taking those readings. Where the decision is one of acceptance or rejection of an individual item based on the result of a certain measurement or observation, there is an all too human tendency to make rapid and sometimes inaccurate readings. On the other hand, when the disposal of the entire lot depends on the accuracy of *each* individual reading as reflected in the calculated average value and the variability of these readings as indicated by the range or standard deviation chart, the natural tendency is to be more precise.

Sheet Circles

One of the early applications made of statistical sampling inspection was in the inspection of sheet circles. Large tonnages of aluminum sheet are sold as blanked discs to customers who prefer to have the aluminum producer perform this first operation in the fabrication of their end product. In a sheet and plate mill, this product seemed to be the logical starting point for using statistical sampling methods because of the relative ease of handling to obtain the desired sample.

A single-sampling plan was first instituted for this purpose several years ago after preliminary investigations to determine the reliability of a sample, taken not strictly in a random manner, in detecting a sub-

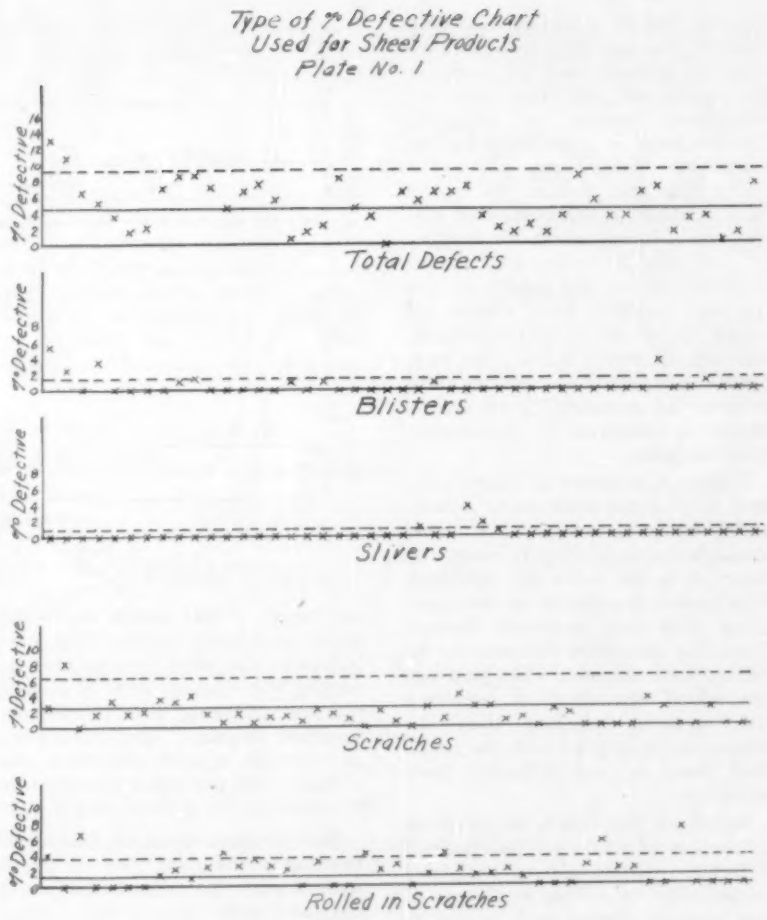

Figure 11

standard lot. Sheet circles normally arrive on the inspection floor stacked on skids, the number of stacks per skid depending on the diameter of the circle. A lot might consist of one or more skids. The most practical manner of taking the sample, naturally, is to take a representative number from each stack on each skid comprising the lot.

While this is not strictly a random sample, it is far closer to a random sample than might appear, if it is recognized that these circles are handled and as a result are shuffled to a considerable extent several times before inspection. As the circles come from the blanking press, they are stacked at random on skids to be conveyed to the annealing furnace. Here they are again handled in a similarly non-patterned manner as they are removed from the skids for placement in a conveyor type annealing furnace. At the exit end of this furnace, the circles are again placed on the skids in a random manner in building up the stacks from the tops of which the samples are taken for inspection. Investigations have demonstrated that this sampling procedure is representative.

Figure 9 is a picture of a lot of circles being inspected under this system. The inspector has taken an equal number of circles from each stack shown on the skid and is examining the sample.

Progressing from this single-sampling plan, there was developed a very efficient system of multiple sampling as the annealed circles are taken from the conveyor of the annealing furnace. With this system a series of samples are taken at somewhat regular intervals during the annealing operation of each lot of circles, as they are being removed from the furnace. Figure 10 shows

the exit end of a wicket annealing furnace. The two girls in the picture have the primary task of removing the circles and stacking them for subsequent packing and shipping. The inspector is identifiable by the micrometer in his hand.

The plan used was set up on the basis of multiple samples of 20 circles each. In operation, the inspector will take 20 circles with representation across the width of the conveyor, evaluate these circles and record under the proper classification any defectives found. This procedure is repeated at intervals until evidence of acceptability or rejectability is obtained in accordance with the plan.

If there is evidence of rejectability or if there is not evidence of acceptability by the time the lot has passed through the annealing furnace, the material is set aside for detailing. Lots proven acceptable by the sampling plan are removed directly from the annealing furnace to be packed and shipped. This plan has the added advantage of requiring less material handling than the single-sampling plan with the result that there is less difficulty from scratches.

Based on the results of sampling inspection of sheet circles, percent defective control charts are used periodically to obtain a picture of the level of quality with regard to total defects and individual defects. Figure 11 shows representative charts of this type. It can be seen from this series of charts that scratches were the greatest cause for rejection of the material represented.

Ingot Castings

With the introduction of induction heating of cast-to-length ingots, difficulty was being experienced because of variation in weight of the ingot. This problem was largely one of mass effect where under the established cycle too large a piece failed to heat to the required temperature and too small a piece heated excessively. It was determined that most of this variation was attributable to length and, therefore, this dimension was put on $\bar{X}$ and R chart control.

Figure 12 is a panorama of three stages of this application. The first section represents the early charting and shows the process to be in control. The ordinate scale is average length of five ingots above the minimum desired length. This chart indicates that the process was in control but that the level of control was not sufficiently good to meet the specified tolerance. Engineering assistance was sought, therefore, and a gage was perfected to assist in maintaining the desired length.

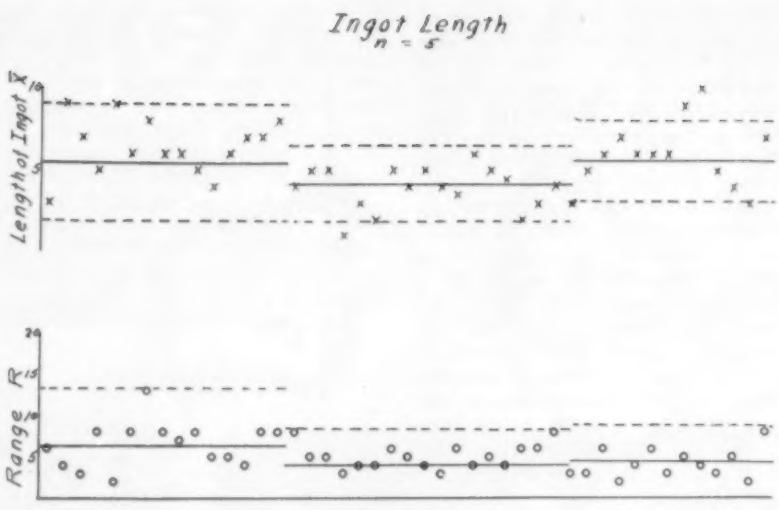

Figure 12

The center section of this chart represents the next cast of ingots poured with the help of the newly designed gage and of the control charts posted for the information of the operating personnel. It will be noted that considerable improvement was effected.

In the last section, however, it was decided as an experiment not to post the control charts but merely to take the readings and post them in tabular form without any indicated warning limits. It is interesting to see how the level of the production changed when the charts were removed. The charts are now routine on this application and better uniformity is being obtained in fabrication as a result of more consistent heating.

Ingot Scalping

In plant operations, it is sometimes found that a large part of the benefit of control charts can be obtained without actually maintaining such charts on the floor but by giving the operating people a "rule-of-thumb" method of determining the need for corrective action for the pertinent process. This approach was resorted to as a control on the scalping of ingot for magnesium alloy sheet fabrication. This application is mentioned here because of the general applicability of such an approach where there might not be justification for keeping charts but where a scientific "rule-of-thumb" is desired.

In this operation, it had been the practice to weigh the group of ingots before and after scalping to check the amount of surface metal being removed. Although a nominal thickness to be removed was established, the problem was one of deciding when the deviation from the desired nominal was considered excessive.

A statistical study of the process was made to determine its standard deviation. From the results of this study, limits were calculated for the total weight of scalpings to be expected under normal chance variations based on the desired depth of cut and the various sample sizes within which a load of ingots being processed would normally fall. In this particular application the number of ingots comprising the lot covered from 15 to 20. Tables such as

Table II

No. of Ingots in Load	Average Total Scalp Loss Pounds	Permissible Limits max.	min.
20	470	501	439
19	447	477	417
18	423	452	394
17	400	428	372
16	376	403	349
15	353	380	326

the example shown in Table II were prepared for each size of ingot being used.

These tables were made available to the operating personnel and have been favorably received and used as a guide in controlling the scalping operation. Although some of the advantages to be obtained by the use of charts such as early detection of trends, the possibilities of improving the process by following through on indications of improvements, etc. are not as evident under this approach; it does, nevertheless, serve a useful purpose. Such approach may also be used as a wedge to the eventual use of charts where a gradual selling job is required.

CONCLUSION

The applications discussed in this article were selected as an assortment depicting the diversity of use to which Alcoa has successfully applied modern quality control techniques in its operations. They do not represent any particularly new principles. The article was prepared primarily with the hope that these actual experiences might be of interest and that from them might come encouragement to others to investigate the possibility of obtaining similar benefits.

Although quantitatively the utilization of control charts and sampling plans in Alcoa's operations is not outstanding, it is felt that the success of the applications that have been made definitely points to many more benefits yet to be derived from an ever extending use of the principles of statistical quality control.

F Table Significance Tests For Two Small-Sample Means

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Practical problems frequently arise that call for the use of the t test for a measure of significance between two sample means. This test is directly applicable to engineering situations concerned with the comparison of two random samples. It provides a sound basis for deciding whether or not the observed difference between the two sample means could reasonably have occurred as a sampling fluctuation from essentially the same set of operating or experimental conditions. This article will show that a t test can be made as a t^2 test by use of the well-known F table, thereby avoiding some of the tedious arithmetic associated with the traditional t test. Although this fact is not a new discovery (see Ref. 1, 2), it may not be generally known to many in the SQC field, and hence should be of interest as a possible means of simplifying t test computations.

If we are comparing the means of two random samples, Fisher's t test formula is:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{S}} \sqrt{\frac{N_1 N_2 (N_1 + N_2 - 2)}{N_1 + N_2}} \qquad (1)$$

where N_1 and N_2 are the sample sizes, $\bar{X}_1$ and $\bar{X}_2$ the means, and S the pooled sum of squares from the two samples. This can also be written:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{\Sigma x_1^2 + \Sigma x_2^2}{N_1 + N_2 - 2}}} \Bigg/ \sqrt{\frac{1}{N_1} + \frac{1}{N_2}} \qquad (2)$$

where the Σx^2 are the total squared deviations from the means.

Hence,

$$t^2 = \frac{(\bar{X}_1 - \bar{X}_2)^2}{\left[\frac{\Sigma x_1^2 + \Sigma x_2^2}{N_1 + N_2 - 2}\right]} \Bigg/ \left(\frac{1}{N_1} + \frac{1}{N_2}\right) \qquad (3)$$

and t^2 thus defined follows the F distribution with 1 and $N_1 + N_2 - 2$ degrees of freedom. (See Ref. 1, 2) It follows that by using t^2 and the F table rather than t and the t table, we eliminate the most tedious part of all t tests, namely the square root extraction. Tables of F are, of course, available in standard texts for levels of significance of five percent and one percent.

It should be noted, however, that we buy this gain in simplicity at the expense of two advantages that go with the traditional t test:

(1) more probability levels are available in a t table than are provided in most of the text book F tables; and

(2) the t^2 test using the F table is a two-tail test; i.e., it is concerned only with the *magnitude* of the difference in means, not with testing whether one mean is significantly *greater* than the other, as can be done with a t test and t table.

We shall now recommend a procedure for carrying through the above t^2 test in a simple manner. It will be assumed that an F table and a table of reciprocals are available.

The raw materials of the test are the means and sums of squared deviations. Those using desk calculators will usually want to obtain these in one run from the original data. This is done by the successive squaring of each observation using the "accumulative multiplication" key (Monroe and Friden) or by merely not clearing the dials (Marchant). This procedure gives us ΣX^2 and ΣX, the sum of squares and the sum of the data. Adding the data separately provides a check, lest, as frequently happens, an intermediate sum has been omitted. Using these figures, $\overline{X} = \Sigma X/N$ and $\Sigma x^2 = \Sigma X^2 - (\Sigma X)^2/N$. If the data are few, we can use the basic formula

$$\Sigma x^2 = (\overline{X} - X_1)^2 + (\overline{X} - X_2)^2 \ \ldots\ldots\ (\overline{X} - X_N)^2$$

where $\overline{X}$ and N refer to the particular sample to which the formula is applied.

The test proceeds as follows under the formula

$$F = \frac{(\overline{X}_1 - \overline{X}_2)^2}{S'^2} \Bigg/ \left(\frac{1}{N_1} + \frac{1}{N_2}\right)$$

Step 1: Subtract the means and square.

Step 2: Form the pooled sum of squares:

$$S'^2 = \frac{\Sigma x_1^2 + \Sigma x_2^2}{N_1 + N_2 - 2}$$

Step 3: Add the reciprocals of N_1 and N_2.

Step 4: Multiply the pooled sum obtained in (2) by the sum of the reciprocals obtained in (3).

Step 5: Divide the squared difference between means obtained in (1) by the product obtained in (4).

Step 6: Compare with a standard F table for 1 and $N_1 + N_2 - 2$ degrees of freedom. (The left-hand column, row $N_1 + N_2 - 2$, in the F table.)

Examples:

1. Burning Time (seconds)
(Floating Smoke Pot, Mark V, Model 2)

Type I			*Type II*		
480	570		525	540	
510	570		510	570	
525	495		555	600	
660	480		540	555	
495	525	$N_1 = 11$	495	570	$N_2 = 13$
615			555	675	
			570		
$\Sigma X = 5925$			$\Sigma X = 7260$		
$\Sigma X^2 = 3{,}225{,}825$			$\Sigma X^2 = 4{,}078{,}350$		
$\overline{X}_1 = \Sigma X/N = 538.6$			$\overline{X}_2 = \Sigma X/N = 558.5$		

Step 1: $(\overline{X}_1 - \overline{X}_2)^2 = (538.6 - 558.6)^2 = 396.01$

Step 2: $\Sigma x_1^2 = \Sigma X^2 - (\Sigma X)^2/N = 3225825 - (5925)^2/11 = 34405$

$\Sigma x_2^2 = \Sigma X^2 - (\Sigma X)^2/N = 4078350 - (7260)^2/13 = 23919$

$$S'^2 = \frac{\Sigma x_1^2 + \Sigma x_2^2}{N_1 + N_2 - 2} = \frac{3405 + 23919}{22} = 2651.1$$

Step 3: $(1/N_1 + 1/N_2) = (1/11 + 1/13) = 0.16782$

Step 4: $(2651.1)\ (0.16782) = 444.93$

Step 5: $F = 396.01/444.93 = 0.89$

The F-table shows a five percent value of 4.30 for $N_1 + N_2 - 2 = 22$ degrees of freedom, which is larger than 0.89. Therefore, no significant difference between these means has been shown.

2. Burning Time

Type I			*Type II*		
585	570		660	780	
615	645		630	660	
600	645		705	720	
600	590	$N_1 = 10$	705	735	$N_2 = 9$
555	645		825		
$\Sigma X = 6050$			$\Sigma X = 6420$		
$\Sigma X^2 = 3669550$			$\Sigma X^2 = 4609800$		
$\overline{X}_1 = 605$			$\overline{X}_2 = 713.3$		

Step 1: $(\overline{X}_1 - \overline{X}_2)^2 = (605 - 713.3)^2 = 11728.89$

Step 2: $\Sigma x_1^2 = \Sigma X^2 - (\Sigma X)^2/N = 3669550 - (6050)^2/10 = 9300$

$\Sigma x_2^2 = \Sigma X^2 - (\Sigma X)^2/N = 4609800 - (6420)^2/9 = 30200$

$$S'^2 = \frac{\Sigma x_1^2 + \Sigma x_2^2}{N_1 + N_2 - 2} = \frac{39500}{17} = 2323.5$$

Step 3: $(1/N_1 + 1/N_2) = (1/10 + 1/9) = 0.21111$

Step 4: $(2323.5)\ (0.21111) = 490.51$

Step 5: $F = 11728.89/490.51 = 23.9$

This exceeds the table one percent level of F for 17 degrees of freedom, which is 8.40, indicating a highly significant difference between means.

References

1. Kenney and Keeping, *Mathematics of Statistics*, D. Van Nostrand & Company, 1951, p. 183.
2. Mood, A. M., *Introduction to the Theory of Statistics*, McGraw-Hill, 1950, p. 206.
3. Yule and Kendall, *Introduction to the Theory of Statistics*, Griffin & Company Ltd., London, 1950, Sec. 21.12, pp. 491.
4. In the author's opinion, computation can be further simplified by the use of a factor incorporating the numerous N_1 and N_2 parts of the equation. Such a device was presented in the Chemical Corps Engineering Agency paper "Tables of Q for a simplified test of significant difference," Army Chemical Center, Md., 7 January 1953.

The Use of the Band Chart in Quality Control[1]

MORRIS M. LIGHTSTONE

Ford Motor Company

It is a well known statistical fact that sampling inspection by measured variable yields more information than attribute inspection for samples of equal size. This fact has contributed, in the past, to a trend away from the use of go no-go gages, toward the use of dimensional gages such as the dial indicator, with a consequent gain in information for each item inspected.

Where repeated dimensional inspection, over a period of time, has established the process mean, $\overline{X}'$, and standard deviation, σ', (or range) with acceptable degree of reliability, it becomes possible to change from that type of inspection to attribute inspection without appreciable loss of information. Interest in this fact has recently led to the development of appropriate process control and sampling plans, some of which have been described in publications of the American Society for Quality Control.[2,3]

The Timken-Detroit Axle Division has for several years employed a method known as the band chart[4], embodying this principle, for processes which are in a state of statistical control. The band chart is an example of an attribute, narrow-limit gage plan, and its use can lead to important advantages relative to dimensional inspection. When using it, we prefer that the mean and standard deviation of the process under consideration be well established. The band chart, pictured in Fig. 1, has replaced the conventional $\overline{X}$ and R control chart with its dimensional scale for plotting average and range.

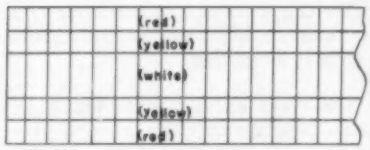


Figure 1—Band Chart

The broad white inner band represents the dimensions which are satisfactorily close to the blue print average. These dimensions might be termed "within narrow-limit gage." The bands immediately above and below are yellow and represent dimensions which appear to be somewhat high or low, but are still within tolerance. A measurement falling within a yellow band may be a warning of impending trouble. The two outer bands are red and represent dimensions out of tolerance. Experience at Timken indicated that for certain machining operations, the limits of the "within narrow-limit gage" white band could be set at $\overline{X}' \pm 30\%$ of tolerance, with the upper and lower "out of narrow-limit gage but within tolerance" yellow bands each extending over 20 percent of tolerance.

A sample of seven is selected and checked with a fixed NL-gage (e.g. snap gage) set at $\overline{X}' \pm 30\%$ of tolerance. The number of pieces which are satisfactory when checked with this gage is marked in the white band. Pieces which fail the NL-gage are checked with a fixed limit gage set at the engineering tolerance and are then classified as acceptable-high, acceptable-low, oversize, or undersize. The appropriate numbers are marked in the upper and lower yellow and red bands.

The results shown in Fig. 2 are considered to indicate satisfactory performance and the process allowed to continue.

All other conditions are considered to indicate unsatisfactory performance and point to the need for process adjustment.

What is the probability that the Band Chart will prevent the following two types of error:

(1) Taking "corrective action" such as rejection of items, machine adjustment, retooling, when such action is, in fact, unnecessary?

(2) Failure to take "corrective action" when it is necessary?

An examination of the operating characteristics of the band chart sampling plan in Table I affords the best answer to that question. The following assumptions have been made in calculating the values in Table I:

(a) The distribution of dimensions is normal.

(b) The true mean of the process is reliably known, and is subject to shifting.

(c) The true standard deviation, σ', is known and remains constant.

(d) The tolerance limits are taken to be $\overline{X}' \pm 3\sigma'$.

For comparison, there is also included a measured variable sampling plan with sample size of five, and with control limits at $\overline{X}' \pm 1.34\sigma'$.[5]

Column 3 of Table I gives the probability that a sample value $\overline{X}$ will fall within the limits $\overline{X}' \pm 1.34\sigma'$ if the process mean has departed from the standard, $\overline{X}'$, by the amount shown in Column 1, when a measured variable sampling plan is used with sample size n=5. Column 4 gives the corresponding probabilities when the band chart is used. Thus, if the process mean is $0.5\sigma'$ from $\overline{X}'$ (and the percent defective is correspondingly 0.64 percent), then the probability is 0.9701 that the sample value of $\overline{X}$ will fall within

[1]The writer would like to express his appreciation to Mr. J. Rayer, Sr., Quality Supervisor, Timken-Detroit Axle Division of Rockwell Spring & Axle Company, for authorization to use the Band Chart materials presented in this article.

[2]*The Use of Limit Gages in Process Control*, Arthur E. Mace, *Industrial Quality Control*, January 1952, Vol. VIII, No. 4, pp. 24-31.

[3]*Narrow Limit Gaging*, Ellis R. Ott and A. B. Mundel, *Industrial Quality Control*, March 1954, Vol. X, No. 5, pp. 21-28.

[4]Developed by Ed J. McCauley and J. H. Meroz of the Quality Control Department.

[5]There is no necessary connection between these two plans; they are compared simply because the probabilities of the two are of the same order of magnitude.

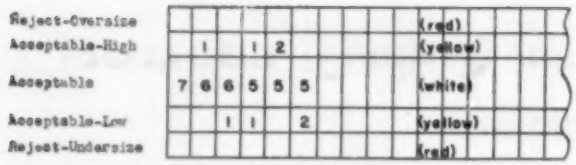


Figure 2—Band Chart Showing Samples Which Are Satisfactory

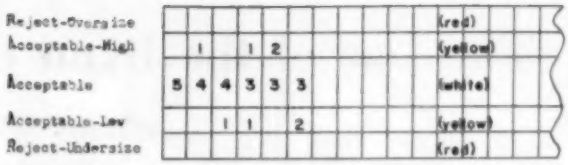


Figure 4—Band Chart Showing Samples Which Are Satisfactory

the control limits and that no corrective action will be taken; the probability is similarly 0.9301 that the band chart will indicate satisfactory performance, and that no corrective action will be taken.

The probabilities in Column 3 are obtained from a table of areas under the Normal Curve, with limits depending on $K\sigma'/\sqrt{5}$, while Column 4 is derived from the multinomial expansion of $(p_1+p_2+p_3+p_4+p_5)^7$, where p_i is the probability that a sample item will be recorded in the i-th band.

The probabilities for the two plans give similar results, with the measured variable plan showing a small advantage in avoidance of the two types of errors indicated above. The operating characteristic curves are compared in Figure 3.

For certain processes where the $6\sigma'$ spread is very narrow relative to the control limits, it has been found useful to relax control limits to $\bar{X}' \pm 1.61\sigma'$. The operating characteristics of this measured variable sampling plan are compared in Table II with a band chart plan based on a sample of five.

The band chart is modified in this example so that the conditions shown in Fig. 4 are assumed to indicate satisfactory performance.

The probabilities of the two plans are of the same order, though the band chart plan will lead to some unnecessary corrective action, and will fail to indicate necessary corrective action, in a few more cases than will the measured variable plan. The calculations for the latter plan are made, as before, from a table of areas of the Normal Curve, and the band chart probabilities are calculated from the multinomial $(p_1+p_2+p_3+p_4+p_5)^5$. Figure 5 shows the two operating characteristic curves.

It can be concluded that the band chart affords about the same degree of protection as the $\bar{X}$ and R Chart against Type 1 and Type 2 errors. In addition, it is considerably simpler to teach and to use the band chart; hence the problem of instructing and training quality control personnel becomes simplified.

The chief advantage of the band chart lies in the fact that it can achieve the same probabilities as the $\bar{X}$ and R Chart with a drastic saving in time. Specifically, the following savings can be made:

(1) Inspection time can be reduced by a substantial amount.
(2) Time spent by inspection personnel in arithmetic calculation and chart marking can be reduced by more than 50 percent.
(3) The amount and frequency of inspection can be increased without a net increase in inspection time.

Reduced inspection time can be brought about by replacing dimensional gages with simpler, more easily used, fixed limit gages, (e.g. non-indicating snap gages rather than dial indicators). This time saving will be offset to a small degree by the fact that some items will require checking with both the NL-gage and tolerance gage.

Arithmetic calculation for the $\bar{X}$ and R Chart has been a costly operation at Timken-Detroit Axle Division, with time requirements unduly great relative to actual inspection time. The band chart eliminates such steps as recording dimensions, computing means, calculating control lines.

The accumulated savings in time permit more inspection, if that appears desirable, without a net increase in inspection time. Larger samples can be used to reduce the risk of error, and more frequent inspections can be made. Inspection at shorter intervals means that systematic assignable causes (e.g. need for tool adjustment or replacement) will usually be detected earlier. Further, such considerations as bad stock or operator peculiarities will be detected more frequently. The latter tend to cause stratification of defective items, and these may be missed entirely if inspection is done at infrequent intervals.

TABLE I—COMPARISON OF THE OPERATING CHARACTERISTICS OF $\bar{X}$ CHART ($\bar{X}' \pm 1.34\sigma'$) AND BAND CHART SAMPLING PLANS

Process Shift (in standard deviations) (1)	Percent of Items Defective (2)	Probability of Not Taking Corrective Action	
		$\bar{X}$ Chart Plan n=5 (3)	Band Chart Plan n=7 (4)
0.0	0.27	.9973	.9719
0.5	0.64	.9701	.9301
1.0	2.28	.7776	.7285
1.5	6.68	.3617	.3430
2.0	15.87	.0705	.0674
2.5	30.85	.0048	.0041
3.0	50.00	.0001	.0001
3.5	69.15	.0000	.0000

TABLE II—COMPARISON OF OPERATING CHARACTERISTIC OF $\bar{X}$ CHART ($\bar{X}' \pm 1.61\sigma'$) AND BAND CHART SAMPLING PLANS

Process Shift (in standard deviations) (1)	Percent of Items Defective (2)	Probability of Not Taking Corrective Action	
		$\bar{X}$ Chart Plan n=5 (3)	Band Chart Plan n=5 (4)
0.0	0.27	.9997	.9836
0.5	0.64	.9935	.9595
1.0	2.28	.9137	.8286
1.5	6.68	.5972	.5516
2.0	15.87	.1916	.2108
2.5	30.85	.0233	.0471
3.0	50.00	.0009	.0026
3.5	69.15	.0001	.0001

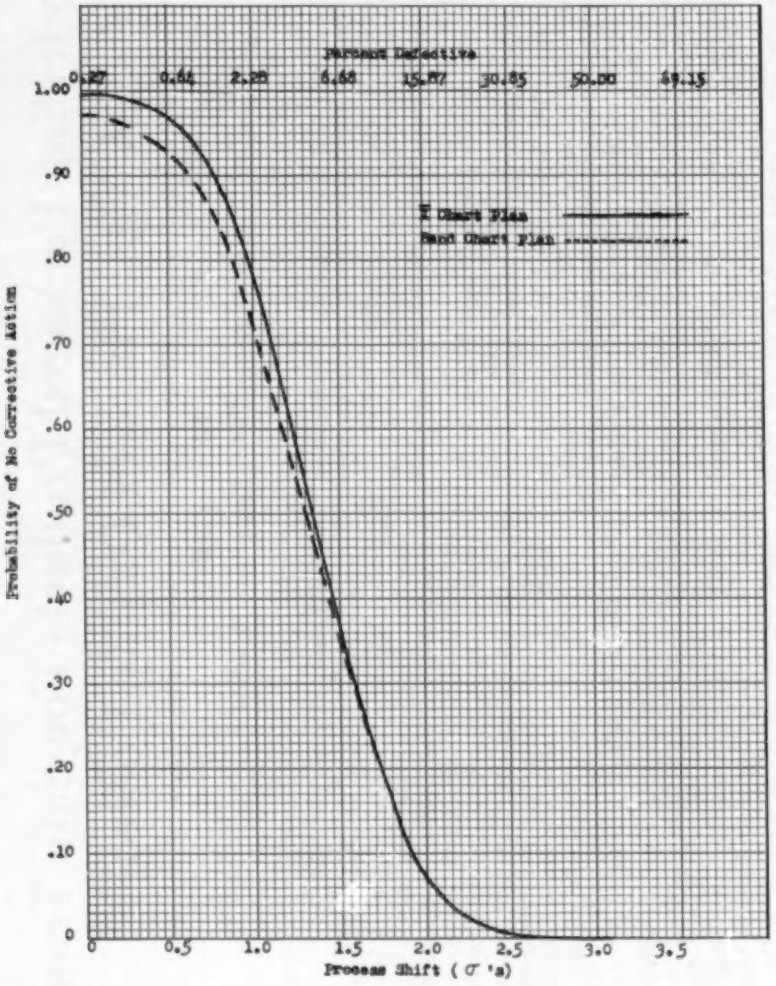


Figure 3—Operating Characteristic Curves for the $\bar{X}$ Chart ($\bar{X}' \pm 1.34\ \sigma'$) and Band Chart Sampling Plans

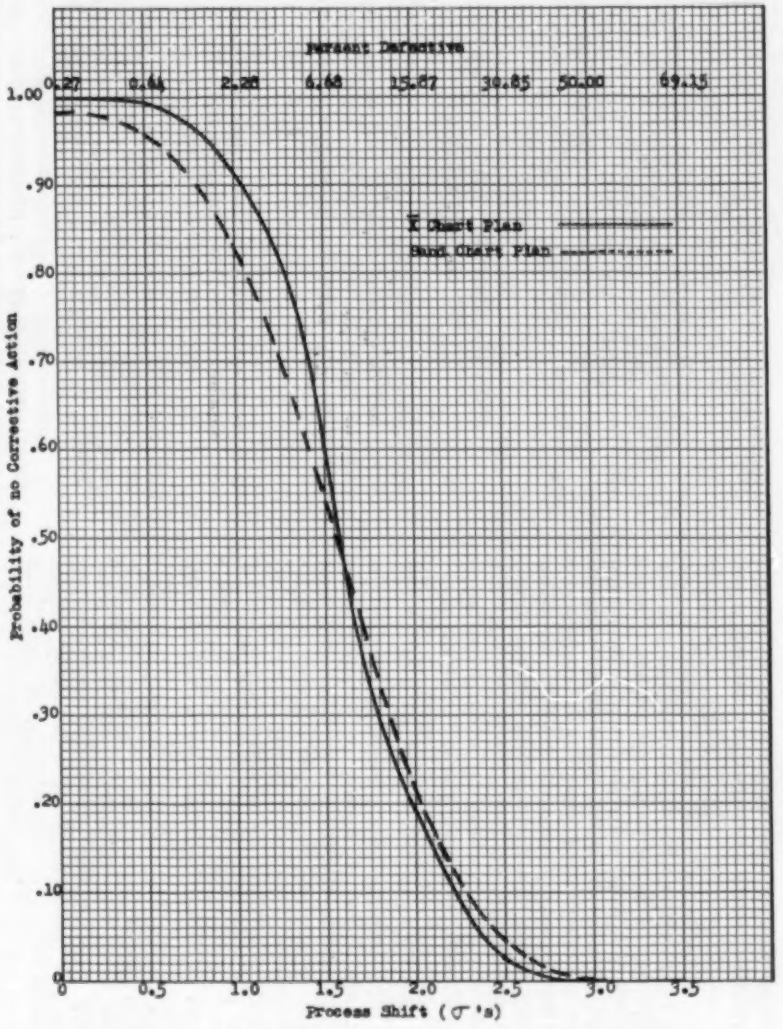


Figure 5—Operating Characteristic Curves for the $\bar{X}$ Chart ($\bar{X}' \pm 1.61\ \sigma'$) and Band Chart Sampling Plans

Pretesting Packaged Products For Safe Transit-- A Vital Phase of Quality Control*

R. F. BISBEE

Westinghouse Electric Corporation, Mansfield, Ohio

ON THE premise that "all engineering, manufacturing and quality control efforts are in vain if the product reaches its destination in a damaged condition," it is obvious that pretesting of the finished packaged product is a vital phase of quality control that has been long overlooked.

Quality control techniques go to great lengths on the control of raw material, material in process, and the finished product, but often that is where they end.

The purpose of this paper is to show that it is just as important to control the packaged product by predetermining if it will stand normal handling and transportation as it is to control any other phase of the product through manufacture, in that subsequent inspection after pre-shipment tests reveals defects that cannot be found in any other way.

The benefits of pretesting on the finished packaged product can be divided into four parts.

1—*A Tool for Better Quality Control*
To help control and maintain a uniform quality of the product by checking and testing a sample of each product produced daily after the Safe Transit tests have been conducted.

2—*A Tool for Reducing Product Losses in Transit*
To assure that the product will stand normal handling and transportation before it is shipped so that it will reach its final destination in good condition.

3—*A Tool for Safely Reducing the Costs*
Having a definite standard for pre-shipping tests, becomes a positive tool in reducing the costs to the "last drop."

4—*A Sales Tool*
The benefits listed above make this program a definite sales advantage in showing the customer that the shipper is doing everything possible to save him trouble and expense by reducing damaged goods.

BACKGROUND OF NATIONAL SAFE TRANSIT TESTING

What It Is

The National Safe Transit Program is a cooperative industry plan which was organized to reduce shipping damage losses. To achieve this end, a number of associations, representing manufacturers of major appliances and allied metal products, transportation agencies, and container manufacturers, have pledged their full support.

The Problem—Shipping Damage

Losses due to damage sustained in the shipments of goods comprise a heavy and wasteful burden on the American economic system. It is estimated that the total volume of losses of all carriers and refused claims is about 500,000,000. A vast effort, as well as money, is required to report, investigate and adjudicate such claims.

Costly legal proceedings must often be invoked. The harmonious relations between the manufacturer and his distributors and dealers are often disturbed and the resulting loss of goodwill injures everyone.

Early Research Work

In 1936 Westinghouse made a check with industry and leading laboratories and found that there was no standard for a pre-shipment test of a packaged product. We found that many attempts had been made by various groups to do something about lowering losses, but because they had no actual approach to the solution, no tangible benefits resulted from these campaigns.

In that same year we undertook to establish and correlate a standard pre-shipping test. To make a long story short, by 1941, working with other manufacturers, we had developed a pre-shipping test and had proved its correlation with actual handling and shipping. As proof of this, our damaged product losses shipped had been reduced from three percent in 1937 to about one percent in 1941.

National Safe Transit Committee Organized

After the war our work was continued, and as of August 9, 1948 a committee was formed known as the National Safe Transit Committee sponsored by the Porcelain Enamel Institute of Washington, D. C. Therefore, this pre-testing procedure *became the first national standard in history on major appliances and allied metal products.*

The Search for a New Approach

The committee was fully aware from the beginning of the magnitude of the task it had been assigned. Many attempts over many years to find a solution to the transit damage problem had been made. The carriers, trade associations, commercial laboratories, research organizations and individual manufacturers had carried on almost innumerable continuous investigations without producing any acknowledged solution of general applicability; nor had all of these efforts succeeded in making any material reduction in the amount of the losses.

A New Approach Needed

The findings and reports of these investigations constitute a comprehensive library of literature on the sub-

*Presented on the program of the 7th Annual Convention, ASQC, Philadelphia, Pa., May, 1953.

ject of shipping damage with which the engineers on the committee were familiar. They knew, however, that although these data were valuable for many purposes, they could not provide the tool we needed for our task. To achieve positive, tangible, measurable results we had to find a way to prevent damage before it occurred.

We were not interested in diagnoses that would effect a "cure" after damage had happened. Fortunately, our experience and research work, mentioned above, pointed the way to this approach.

Analysis of Causes of Shipping Damage

The causes underlying shipping failure may be many and complex. Although we speak of "shipping damage," factors other than those involved in actual transportation may bear a heavy responsibility for the failure. Poor packaging, weak product design, carelessness in manufacturing, all these may be contributory causes.

It was obvious that a solution that failed to integrate all these factors could not work, and an engineering approach to the problem was therefore necessary. This concept of the application of an engineering analysis of the problem became the keystone of the Safe Transit standard procedure.

Necessity for Cooperation

The nature of the task to be performed made it obvious that a program to reduce shipping losses had to be a cooperative effort between industry on the one hand and carriers on the other. It was necessary that there be recognition by each that it shared a responsibility for the losses.

Because Westinghouse Electric Corporation was one of the first to standardize on pre-shipment tests for major appliances and because of our extremely low field transportation losses, the author was selected as chairman. The Organization Chart accompanying this paper gives the names of others appointed to this committee.

PROGRESS TO DATE

Although the program has been in actual operation about four years, it has been adopted by many of the smallest and largest manufacturers in the industry. Manufacturers turning out the major volume of goods within our scope are now members—140 in number, or about 80 percent of the total volume of goods.

Outstanding laboratories have also been certified so that it is now possible for a manufacturer in any locality to have his products Safe Transit tested. There are now 27 certified laboratories.

SOME RESULTS FROM THE PROGRAM

It will be appropriate now to consider a few typical field reports bearing on the four benefits to be expected from participation in the NST pre-shipping test program.

A Tool for Better Quality Control

The true quality of a product *may appear* to meet standards after its completion. Quality control organizations in many industries stop quality control at the end of the assembly lines. At this point true quality cannot be assured until after it is subjected to Safe Transit pre-shipment tests which stimulate actual handling and transportation.

With the many variables in material, material substitutions and workmanship that occur each day on any kind of product, many irregularities appear after transportation tests are made that were not apparent before.

The Safe Transit pre-shipment test first softens up the product by the vibration test that simulates the resonance incurred enroute on railroads and trucks. After vibration the subsequent longitudinal shock, which simulates handling and switching cars, shows up a weakness that would not be disclosed in any other way until after many thousands are made and reported back from the customer. A few examples follow.

Westinghouse Electric Corp., Mansfield Works. Vibration and shock dislodged the temperature control tube from its position in the electric range oven due to being improperly assembled. This would have resulted in improper operation of the oven had it not been found.

Vibration and shock resulted in damage to refrigerator unit tube causing a slow leak. This was due to the improper forming on the assembly line, and might have easily gone unnoticed, resulting in hundreds more being assembled in the same manner and not being discovered until slow leaks showed up in customers' homes.

Broken weld in range leveling feet mounting brackets during Safe Transit test. This showed up as a defect in that the customer could not properly level the electric range, and also presented a possible source of chippage to the range body at the base.

Routing of wires near sharp projections cut through insulation, causing electrical failure.

Electrical connections loosened in National Safe Transit tests due to connections not being sufficiently tight.

Continental Water Heater Co., Los Angeles. National Safe Transit tests conducted at the AGA Laboratories in Los Angeles revealed certain weaknesses that have since been corrected, which improved the product quality.

Day & Night Division, Affiliated Gas Equipment, Inc., Monrovia, California. ". . . we feel that the National Safe Transit Program is proving a considerable benefit to our company to improve quality."

Package Research Laboratory, Rockaway, N. Y. "As an NST-certified laboratory, we have had the occasion to make many National Safe Transit tests. The interesting thing about these tests is that frequently the uncover weaknesses in the product which is being packaged."

A Tool for Reducing Product Losses in Transit

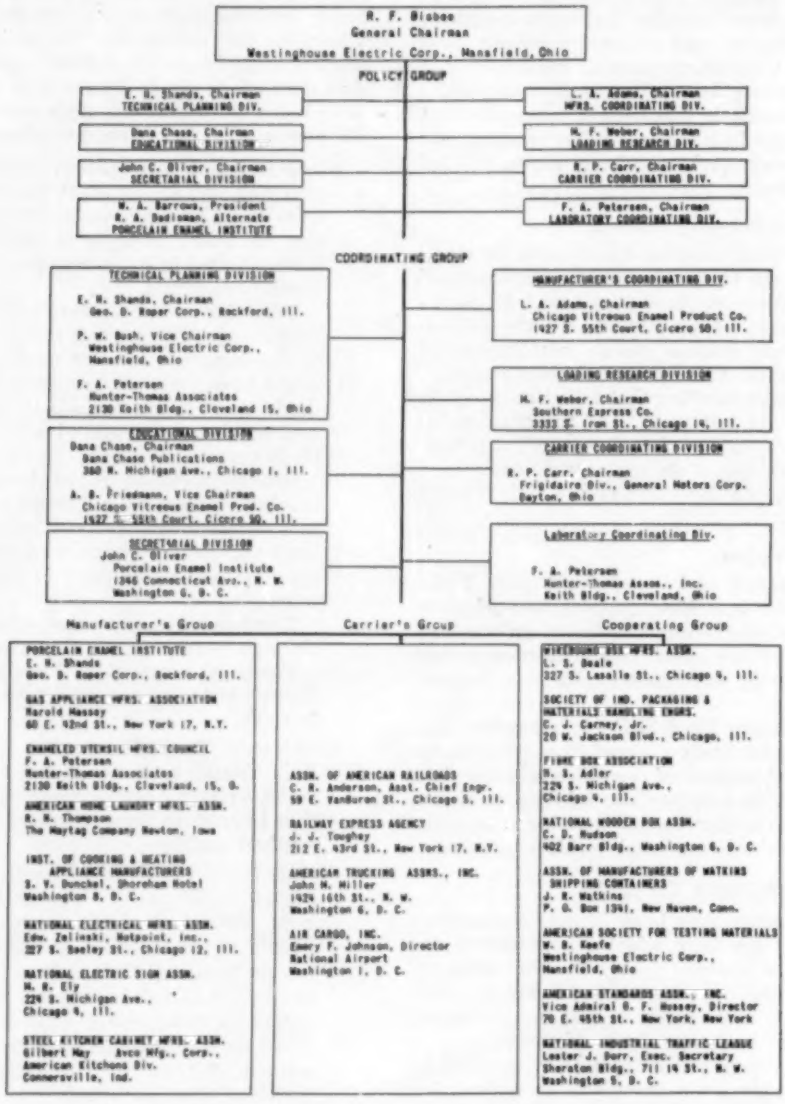
A few examples received from manufacturers typify improvements available through the NST program of daily pre-shipment tests:

Kresky Manufacturing Co., Petaluma, California. "The first part of the NST Program—reduction in transit damages, has been achieved almost 100 percent by us."

Majestic Manufacturing Co., St. Louis, Missouri. This company reports that its claims for transit damages have been reduced over 50 percent since the supplier redesigned its crate to pass the Safe Transit pre-shipment tests.

Globe American Corp., Kokomo, Indiana. "Our damage reports prove beyond any question of a doubt that since using the NST procedures, rich dividends have been paid through a reduction in damaged finished products."

NATIONAL SAFE TRANSIT COMMITTEE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AMERICAN SOCIETY FOR TESTING MATERIALS
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NATIONAL INDUSTRIAL TRAFFIC LEAGUE
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Washington 5, D. C.

The Maytag Company, Newton, Iowa. "This pre-shipment testing has proved of great benefit in that it proves our design and method of packing is satisfactory to withstand the hazards of transportation and handling."

Norge Division, Bork-Warner Corp., Effingham, Illinois. "Safe Transit has paid for itself many times over in reduced damage costs, dealer and distributor goodwill,—"

Moffats Limited, Weston, Ontario, Canada. "At the time of our application for National Safe Transit certification our damages on an overall picture were 24 percent; this has now been reduced to two percent through NST tests."

Perfection Stove Co., Cleveland, Ohio. "We thought the way we were packaging our household ranges was pretty good. But since adopting the Safe Transit pre-shipment testing procedures, we have cut shipping losses from 12 percent to a negligible percentage."

Geo. D. Roper Corp., Rockford, Illinois. "A Daily Safe Transit test detects trouble immediately, and we are able to correct it, which has aided us in reducing our damage in transit to below one percent. The fact that has been particularly surprising to us is that we have reduced the cost of our crating approximately 25 percent."

A Tool for Safely Reducing the Costs

By having a definite pre-shipment standard test, it becomes possible to "milk out the last drop" of cost possible and at the same time be sure that the packaged product will reach its final destination in good condition if handled in a normal manner. How is this accomplished? Here are a few examples:

Day & Night Division, Affiliated Gas Equipment, Inc., Monrovia, California. ". . . Another item which makes the program economically sound is the fact

Inspecting a special gage on a Taft-Peirce 24" x 36" Granite Surface Plate.

New Taft-Peirce GRANITE SURFACE PLATE Keeps Measurements On The Level

FOR PRECISION MEASUREMENTS that require the ultimate in smooth flat surfaces, Taft-Peirce now offers something new in surface plates. A Blue-White Granite Surface Plate. Made of a granite new to toolrooms, it's harder, more wear-resistant, easier to use and care for.

SURFACE ACCURACY is not subject to distortion. Plate is free from all residual stresses. Temperature changes or shock can't warp it.

SMOOTHER, its blue-white grain is extremely fine and even — yet natural pores assure free movement of tools and instruments.

PRACTICALLY INDESTRUCTIBLE, heavy pointed objects dropped on the surface barely powder point of impact. No humps or burrs are raised to impair accuracy. Unique grain direction running 45° to working surface of plate prevents cracking, chipping, or breaking.

RUST-PROOF, no oiling or covers necessary.

LOW POROSITY makes moisture absorption negligible. Tools or work left on this granite surface are not subject to rust.

NON-ABRASIVE, the extra-fine grain won't impregnate readily with dirt or grit particles to cause abrasion. Surface is easily wiped clean and free of foreign matter.

NON-MAGNETIC, it won't deflect instruments. Nor will its soft blue-white color glare or cause disturbing reflections.

ACCURATELY GROUND AND LAPPED, backed by more than 75 years of experience in making precision products, Taft-Peirce Granite Surface Plates are the newest addition to a famous line of layout and inspection equipment.

Write for price list today.

For more information on surface plates and many other items, get your copy of the new Taft-Peirce Handbook.

T-P means Top Precision

THE TAFT-PEIRCE MANUFACTURING COMPANY · WOONSOCKET, RHODE ISLAND

that we have been able to review packaging, and have designed new packages at appreciable savings to our company. Saving which have already been effected have more than paid for the testing expenses which have been accumulated."

Tappan Stove Co., Mansfield, Ohio. "The standard tests have led us to a better crate design. Fortunately, the new crate which was designed to resist the standard tests turned out to be less expensive than the old one."

Westinghouse Electric Corp., Beaver Works. ". . . NST has opened a new field of cost reduction for Beaver operations and the industry." (Mr. Cupps, Supvr. Inspection and Test, shows detailed estimated savings for a six months period on packing materials of $3,760.45. Also a savings of 34,700 lbs. in shipping weights for a six months period at $1.33 average per hundred, or $461.50.)

Easy Washing Machine Co., Syracuse, N. Y. ". . . figures are available showing savings of approximately ten percent on the cost of a container entirely due to NST pre-shipment testing."

Day & Night Division, Affiliated Gas Equipment, Inc., Monrovia, California. "Before the NST program was started, our only recourse was to re-design our containers, ship them to various points for return, then examine them to see what had happened. In one case, after the AGA-NST tests, we were able to modify the crating on one of our water heaters in a manner so that we will realize a saving of about $10,000 a year on this single product."

A Sales Tool

The benefits from the above results definitely promote customer goodwill.

An industry-wide NST conference was held in Chicago, March 16, 1953. The theme of the meeting: "Safe Transit—A Sales Tool for You." Attendance was made up of a large number of leading manufacturers, carrier representatives from railroads, Railway Express, Air Cargo, American Trucking Association, leading laboratories of the country, and many other associations working with us to further this program.

As the main theme of the meeting was "A Sales Tool for You" I shall quote in part a paper by W. H. Murray, Assistant Supervisor of Purchases and Stores of the Georgia Power Company, Atlanta, Georgia.

"We not only buy appliances in carload lots, but we then distribute them to over 100 retail outlets of our own. From these retail stores, we install the merchandise directly in the customers' homes. We have the opportunity to see its condition all along the line, and we also have all of the headaches that arise when merchandise is received damaged.

"Not so many years ago, our warehouses over the state were so filled with damaged appliances, and the cost of repairs had become so great, I think some of us seriously doubted the wisdom of an electric utility company continuing in the business of selling electric appliances.

"But now—thanks to the National Safe Transit Program—we are beginning to see the flood-tide of damage checked. What this program can do in the years ahead to reduce the terrible losses resulting from damage in transit is dependent entirely on the cooperation it receives from all industry and carriers involved.

"No longer can the manufacturer hold his place in the highly competitive market of today who holds to the old ideas that his responsibility ends when he builds a good product. It is also his responsibility to do everything possible to see that it is delivered to the buyer in good condition.

"The National Safe Transit Program has already helped our company in many ways.

"The labels on cartons, placed there by those manufacturers who have qualified under the National Safe Transit Program, which read, 'Make Safe Handling Your Job' have created a lot of interest among our men. It is our belief that the sight of this label actually results in men all along the line giving a little better care to these particuar crates. By using the label, the manufacturer is showing the carriers and his distributors that he is doing everything known to shipping science to see that the product is delivered to its final destination in good condition. We believe the carriers use more care when they know the manufacturer is doing his part.

"It goes without saying that the independent distributors are going to think a long time before they purchase merchandise and appliances from those manufacturers who are not sufficiently interested in their product to cooperate in this great program.

"'LEADERSHIP IN BUSINESS INHERITS THE RESPONSIBILITY OF MAKING PROGRESS. THE NATIONAL SAFE TRANSIT PROGRAM IS PROGRESS —LET'S ALL SUPPORT IT!' In any language this spells 'a good sales tool'."

Because Georgia Power Company really represents the distributor, the dealer down at the customer level, and covers the entire state of Georgia, I believe Mr. Murray's thinking tells a story on "A Sales Tool for You" that is most convincing.

NATIONAL SAFE TRANSIT FILM

As this program is now nation-wide in scope, a colored movie has been prepared which we use around the country for various educational meetings. It took over two years to complete this film. This is an all-purpose film, which shows all of the early correlation work with the carriers and then is followed by showing in detail how each one of the tests is conducted. In addition to this, it covers a lot of background and other interesting information that really make the film complete in every respect.

For example, the early correlation work definitely shows proof of the research work in correlating vibration with actual handling and in-transit conditions, which led to the first national standard recognized by both carriers and a group of manufacturers on a voluntary basis.

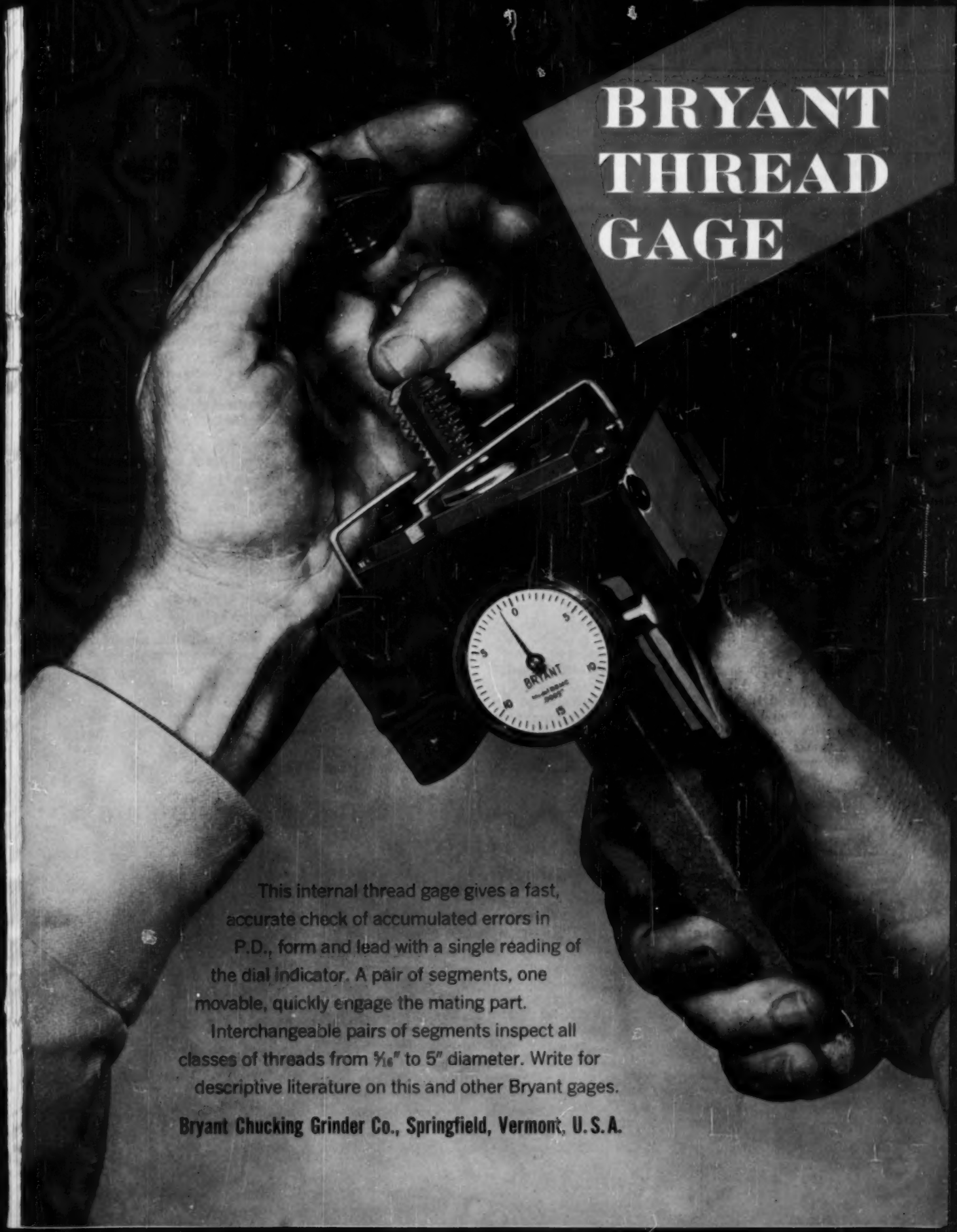
The film shows that all in all some hundred thousand miles of test shipments were completed and data recorded covering the following areas:

Air Cargo Tests

Some 15,000 miles of air cargo tests were made and correlated with the test procedures of the National Safe Transit Program. Four of the major air lines cooperated in the program through Air Cargo, Inc., by carrying test shipments over specified routes and by having technical men cooperate with the Sub-Committee.

Arrangements were made with top personnel of the cooperating lines so that test shipments could be made without attracting attention as special cargo. Attention was given to transfer points so that they would represent a good cross section as to type and location of transfer; such as, transfer from air line terminal in a metropolit area to the airport.

It was found that, in all instances, maximum shock was encountered during handling and not while in transit.



This internal thread gage gives a fast, accurate check of accumulated errors in P.D., form and lead with a single reading of the dial indicator. A pair of segments, one movable, quickly engage the mating part. Interchangeable pairs of segments inspect all classes of threads from 5/16" to 5" diameter. Write for descriptive literature on this and other Bryant gages.

Bryant Chucking Grinder Co., Springfield, Vermont, U.S.A.

The only time shocks were recorded in the 5th zone on the instrument was during loading, handling at airport, and unloading.

Railway Express Tests

Through cooperation with the Railway Express Agency, tests were made under normal conditions of shipment in express cars. Five different railway systems were involved. Here again, the actual shocks during the movement of the railway cars were less than those encountered during the actual loading and unloading.

Test Shipments by Railroad Freight

Dozens of test shipments were made by railroad freight, both carload and LCL. Very close correlation was obtained as a result of these tests. Here again, in practically every instance, it was found that in loading and unloading, shocks were incurred in or approaching the 5th zone. Some shipments did not show 5th zone impact at any point during car movement. Shocks extending into the 5th zone were encountered during car shifting and switching and a few cases where the car apparently went into resonance.

Motor Trucks

Data on truck shipments were obtained through the cooperation of American Trucking Association and its members. These test periods covered over 18 months. The film shows all methods of roads, local deliveries, national and state highways, county and rural roads, etc.

Reprints of the film can be obtained for $150 or can be rented at $10 per showing from National Safe Transit, Dupont Circle Building, 1346 Connecticut Avenue, N.W., Washington 6, D. C.

Summary of Correlation Research

1. The worst shocks under all conditions observed in the majority of cases occurred during handling.
2. The 5th zone established as the minimum shock requirement for the packaged product under the National Safe Transit Program, represents no more than the conditions normally encountered in transportation and handling.
3. Vibration tests are based on the summary of the vibrational data obtained during the many tests with the railroads, express, air cargo and motor trucks.

CONCLUSION

The National Safe Transit Committee and its program have been sponsored by the Porcelain Enamel Industry as a cooperative plan to reduce shipping damage losses in the major appliances and allied metal industries. It is now expanded to take in television and radio manufactures, and later on the scope will be widened to take in many other products. In the interim, many companies not within our scope are using the NST program and are benefiting by the results.

This program provides a new approach to the damage problem, based on the use of pre-shipment test procedures, which, by simulating the hazards of transportation, check the adequacy of the package, the structural resistance of the product design, and the carefulness of the processing. These pre-shipment tests have been approved as representing such hazards by the carriers, the laboratories, and the manufacturers. They have been in use now for over four years and the results achieved with them prove that they do correlate with shipping experience. These tests are now accepted therefore, as scientific, authoritative, and accurate.

The benefits that the industry and the carriers have derived from the National Safe Transit Program have been substantial and will increase as it expands further. There has already been a considerable reduction in the total of damage claims on appliances and allied metal products; some manufacturers have found Safe Transit has cut their overall costs; it has helped others to work out better product designs; still others have found that the standardized tests have shown them where they needed better shop control. Relationships between the manufacturers, the carriers and dealers have been reported to have improved in every instance.

The Safe Transit plan is a basic method for reducing shipping damage that can be applied to all products of all industries where shipping damage is a serious problem. It is our hope that other industries will see in the principles of Safe Transit the means of solving their own problems. We feel sure that if they apply them, they will be as gratified with the results as have been the major appliances and allied metal industries.

Some Experience With The Design of Experiments*

JAMES R. DUFFETT

Guided Missile Reliability Group, Los Angeles Ordnance District

INTRODUCTION

The proper philosophy to be adopted by the experimenter is a desire to select those experimental designs which will yield the largest number of correct decisions concerning the hypotheses which he subjects to experimentation. The experimental designs which implement this philosophy are statistical in nature. With respect to the amount of information which can be obtained from an experiment, the advantages are in favor of the "new look" statistical concept of varying several factors simultaneously, as opposed to the classical concept of holding all factors except one constant.

A particular statistical design which can be employed in many experiments with great success is the replicated factorial. The replicated factorial design consists of (1) selecting at least two factors for study, (2) selecting at least two levels of each factor, and (3) obtaining several (meaning two or more) observations for every combination of levels of the factors selected.

Incorporated in the replicated factorial design are the principles of (1) randomization—in order to obtain results which are not biased—and (2) replication, or repetition—in order to obtain the necessary precision in the results.

REPLICATED FACTORIAL DESIGN

In order to provide a comparison of a good statistical design versus an unsatisfactory intuitive design, a sit-

* Presented at the April 14, 1953, meeting of the Los Angeles Section, ASQC.

uation may be considered in which the replicated factorial represents a good statistical design and the replicated butterfly represents a typical unsatisfactory intuitive design. Experience has shown that the replicated factorial has given excellent information and yielded some very interesting and valuable results whereas the replicated butterfly, if it had been employed, would not have yielded these valuable results. Yet, the butterfly design, along with other intuitive designs, is frequently proposed and furthermore its use insisted upon. Because modern statistical design of experiments has advanced far beyond intuitive designs, it is necessary for all experimental workers to realize and admit this fact and then to implement their experiments by applying the proper statistical design.

A description, comparison, and discussion of a replicated factorial and a replicated butterfly, each with two factors (A and B) at three levels (A_1, A_2, A_3, and B_1, B_2, B_3) follow:

REPLICATED FACTORIAL

	A_1	A_1	A_3
B_1	*	*	*
B_2	*	*	*
B_3	*	*	*

Information which can be obtained from the replicated factorial design:

1) Effect of variation in A's independent of the value of B.
2) Effect of variation in B's independent of the value of A.
3) Interaction of A and B, i.e., whether the effect of A is different at the different levels of B.

REPLICATED BUTTERFLY

	A_1	A_2	A_3
B_1		*	
B_2	*	*	*
B_3		*	

Information which can be obtained from the replicated butterfly design:

1) Effect of variation in B's at level A_2 only.
2) Effect of variation in A's at level B_2 only.
3) No information on interaction of A and B.

The asterisks in the cells above reveal that observations are made for the particular combinations of levels of A and B indicated whereas the absence of asterisks reveals that observations are not made for those combinations thus indicated. Further, we shall assume that there exist n observations in every cell (i.e., one observation on each of the n articles in each cell) which contains an asterisk, thus resulting in an *equally replicated* design. The k-th observation occurring in i-th column and the j-th row will be denoted by x_{ijk}. (The choice of three levels apiece for the factors A and B was made in order to facilitate the comparison between the replicated factorial and the replicated butterfly. The choice of the number of levels for the factors A and B could have been any desired—e.g., four levels for A, A_1, A_2, A_3, A_4, and two levels for B, B_1, B_2).

The foregoing *equally replicated factorial* can be described by the following mathematical model:

$$x_{ijk} = u + a_i + b_j + c_{ij} + e_{ijk},$$

where

- u in the general mean and is the same for all cells
- a_i is the effect of the i-th column and is the same for all cells in the i-th column
- b_j is the effect of the j-th row and is the same for all cells in the j-th row
- c_{ij} is the interaction of A and B and is the same for all observations in the A_i, B_j cell
- e_{ijk} is the experimental error associated with the x_{ijk} value and is due to uncontrolled factors.

The assumptions underlying the mathematical model are the following:

(1) The effects—u, a_i, b_j, c_{ij}, and e_{ijk}—are additive

(2) The e_{ijk}'s come from a normal population with mean 0

(3) All cells have the same population variance σ^2

(4) The x_{ijk}'s are random and independent observations

The method of analyzing the observed data is the familiar analysis of variance in which the total variability is partitioned into components attributable to A, B, A × B interaction, and experimental error. The F ratios, with the correct numbers of degrees of freedom, are calculated and tested for significance. Of course, the factorial design can include more factors than just the two factors A and B.

A few actual engineering situations in which the factorial design can be used are the following:

(1) Construction of firing tables. The factors of interest include quadrant angle of elevation and propellant temperature.

(2) Measuring of "Between Operators (or Operational Teams)" variability along with other factors of interest.

(3) Environmental testing. The factors of interest include vibration, shock, and temperature. Very large interaction effects are encountered.

(4) Equipment performance when the factors of interest include (a) method of transportation, (b) method of storage, and (c) aging period.

In addition to determining whether an effect is significant, the experimenter usually desires to determine the mathematical form (i.e., linear, quadratic, etc.) of the effect. In many cases it is known beforehand that particular factors do have significant effects; therefore, the experiment is performed in order to determine, or confirm, the mathematical form of these effects and to fit curves, by least squares methods, to the observed data.

Let us assume that at the B_2 level, the factor A has a linear effect on the variable (x_{12k}) undergoing observation and measurement—the observed data being recorded in the cells. This assumption means that for a numerical value for B_2, a straight line relationship exists between x_{12k} and A_i within the limits of the random experimental errors assumed in the mathematical model. Likewise, assume that the effect of factor A is linear at the B_1 and B_2 levels. The absence of interaction between factors A and B means that these straight lines are parallel. In the replicated factorial design, evi-

dence of interaction can be obtained —the existence of interaction means that the straight lines have different slopes, and the absence of interaction means that the lines have the same slope and thus are parallel. Even if there is no evidence of interaction (i.e., the design did not detect interaction as being significant), the replicated factorial demands that observations be made at all levels of A for B_1 and B_3 and not just at the A_2 level.

In contrast, the replicated butterfly design will yield no information on interaction. Since the effect of factor A is assumed linear, this design will give us a straight line at the B_2 level, and at the B_1 and B_3 levels all that is obtained are observations made at the A_2 level. Whereas the replicated factorial gives three lines, the replicated butterfly gives one line and two points, where these points are the means of the observations recorded in the A_2, B_1 and A_2, B_3 cells. Of course, through these two points can be fitted (a) lines parallel to the line at the B_2 level or (b) lines of other slopes if such prior knowledge exists concerning the numerical values for the slopes of the lines.

Even in those cases where three parallel lines give the correct fit for the B_1, B_2, and B_3 levels, the replicated factorial gives a higher accuracy in the use of the lines for estimation purposes.

The foregoing does not mean a butterfly must never be used. It would not be bad if the mathematical forms of the effects are definitely known beforehand. However, this is seldom the case because even slight modifications in the article undergoing experiment may result in completely unpredictable results regarding the significance of main effects and interactions and the types of relationships between the x_{ijk}'s and the A's and B's.

In any event, the first experimental design to be used in the evaluation of a new article should be a good statistical design, in this particular case represented as a replicated factorial. Even if the same total number of observations were used for both designs considered in this paper, the replicated butterfly would not be able to uncover significant interactions. Neither could it reveal that the effects of variation in A and B were significant at *all* levels of the other factor.

With regard to the problem concerning whether the variation in the levels of A cause a significant variation in the "within cell" variances of the observations, replicated factorials have often uncovered very important results whereas the replicated butterfly could not have done so. The method employed was the running of a regular analysis of variance on the logarithms of the "within cell" variances of observations.

If insistence is made upon the replicated butterfly, then the advice to be offered is, if at all possible, to conduct the experiment as a replicated factorial and then extract the butterfly part of it and present it to those who demanded the butterfly.

There exist other types of intuitive designs—e.g., every conceivable type of allocation of observations in the individual cells. This could mean that some cells would contain several observations, other cells only one or two observations, and still other cells no observations at all. Possibly a considerable percentage of the effort of mathematical statisticians could profitably be devoted to research in the analysis of some of these strange intuitive designs so that even if experimenters do break all kinds of rules in good statistical design, the analysts will still be able to salvage the experiment as much as possible. For example, a regression analysis performed after a poor design may salvage a great deal of information from the experiment.

The big selling point in favor of a replicated factorial design is the fact that, at the present time, an elaborate and thorough method of analyzing an experiment designed in this manner does exist. If a replicated factorial design had been proposed for an experiment performed 50 years ago, it would have been an intuitive design, since no correct method for analyzing the results obtained from this type of design existed at that time.

An important function of the Guided Missile Reliability Group is to assist in the statistical design of environmental test programs of missile components. The environments considered are vibration, shock, temperature, acceleration, humidity, air density, etc. The interactions between some of these factors are terrific—e.g., vibration, shock, and temperature. In order to obtain evidence concerning the existence of interaction, the replicated factorial is indispensable. There are many other development situations which have this environmental testing problem. The replicated factorial will not solve all of the problems; however, it will solve a very high percentage of them.

OTHER STATISTICAL DESIGNS

Statistical designs other than the replicated factorial may be employed. Among these are the following:

A. Fractionally replicated factorial;* Latin Squares and Greco-Latin Squares; Incomplete Block Designs.†

B. Analysis of Covariance. This technique is valuable in stripping out and measuring the effect of an important factor when it can't be controlled at several levels.

C. Control Charts. Control charts can be employed to detect significant variations. Bicking in Reference 3 has given an illustration of their use in testing for a significant variability between operators.

Some of the foregoing designs are of especial value if the use of a replicated factorial would entail a prohibitive cost. However, certain information is lost by employing these designs which do incorporate smaller sample sizes. For example, the Latin square gives no interaction information.

CONCLUSIONS

The replicated factorial design gives information both on the main effects and on the interaction of factors.

The length of the spectrum of values for each factor should be selected intelligently and should pretty much cover the range of values for which the article undergoing experiment has been designed to operate.

If at all possible space at equal intervals the test levels of each factor. There are two reasons for this

1) The equidistant spacing provides a quick visual aid in thinking and a quick guess on whether a relationship is linear or not

* For an example of a fractionally replicated factorial, see Bicking's paper on a 1/6 replicated factorial (Ref. 4)

† For some examples of incomplete block designs, see Harshbarger's papers on rectangular lattices. (Refs. 13, 14, 15, 16)

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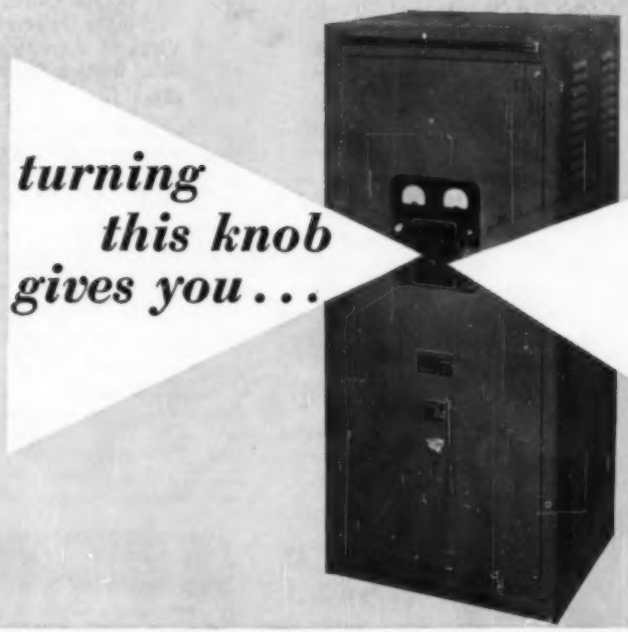

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*Reg. U. S. Pat. Off./**Model SR2 uses a circuit device patented by Wm. J. Brown.

2) The equidistant spacing facilitates the fitting of orthogonal polynomials to the data

The same number of observations should be placed in each cell, thus giving an *equally replicated* factorial. Life is too short to become involved with having to analyze a factorial with unequal cell frequencies.

More emphasis must necessarily be given to the Type II error—i.e., the error of accepting the hypothesis of no effect when it is false—in expensive experiments on complex electromechanical equipment. These expensive experiments must be designed so that there exists a sufficiently high probability of detecting those differences which are considered important to detect.

There exists a need for methods which are better—more powerful—for analyzing a table of variances than the method of running a regular analysis of variance on the logarithms of the "within-cell" variances.

The performance of an article improves with time. This improvement in performance is usually reflected in a reduction in the variation of the observations made on the performance of the article. Therefore, as the variation in the observations decreases, the precision of the measuring instrument must continually be re-examined in order to be sure that it is still capable of doing the job. However, the present tendency seems to be to use too highly precise instruments when cheap, crude instruments would do the job in a satisfactory manner.*

References

1. Anderson, R. L. and Bancroft, T. A., *Statistical Theory in Research*, McGraw-Hill Book Co., New York, 1952
2. Bicking, Charles A., "Some Uses of Statistics in the Planning of Experiments," (Presented originally at a meeting of Sub-Committee B-5, on Sampling, Presentation and Interpretation of Data, of Committee D-13 on Textile Materials of the American Society for Testing Materials at the Park-Sheraton Hotel, New York, Oct. 17, 1951) *Industrial Quality Control*, Vol. X., No. 3, January 1954, pp. 20-24.
3. Bicking, Charles A., "The Reliability of Measured Values. Part II—An Illustrative Example," *Photogrammetric Engineering*, Vol. XVIII, No. 3, June 1952, pp. 554.558
4. Bicking, Charles A., "The Role of Statistics in Increasing the Productivity of Industrial Research," *Industrial Quality Control*, Vol. IX., No. 4, January 1953, pp. 1-4
5. Bradley, Ralph Allen, "The Distribution of the t and F Statistics for a Class of Non-Normal Populations," *Virginia Journal of Science*, Vol. 3 (new series) No. 1, January 1952, pp. 1-32
6. Churchman, C. W., *Statistical Manual. Methods of Making Experimental Inferences*, Pitman-Dunn Laboratory, Frankford Arsenal, Philadelphia, Pa., June 1951
7. Cochran, W. G. and Cox, G. M., *Experimental Designs*, John Wiley & Sons, Inc., New York, 1950
8. Dixon, Wilfred J. and Massey, Frank J., Jr., *Introduction to Statistical Analysis*, McGraw-Hill Book Co., Inc., New York, 1951
9. Eisenhart, Churchill, "The Reliability of Measured Values. Part I—Fundamental Concepts," *Photogrammetric Engineering*, Vol. XVIII, No. 3, June 1952, pp. 542-54
10. Fisher, R. A., *Statistical Methods for Research Workers*, Seventh Edition, Oliver & Boyd, Ltd., Edinburgh, 1938
11. Fisher, R. A., *Design of Experiments*, 4th Edition, Oliver & Boyd, Ltd., Edinburgh and London, 1945
12. Grubbs, F. E., "On Estimating Precision of Measuring Instruments and Product Variability," *Journal of the American Statistical Association*, Vol. 43, 1948, p. 243
13. Harshbarger, Boyd, "Rectangular Lattices," Virginia Agricultural Experiment Station, Memoir I, 1947
14. Harshbarger, Boyd, "Triple Rectangular Lattices," *Biometrics*, Vol. 5, No. 1, 1949
15. Harshbarger, Boyd, "Near Balance Rectangular Lattices," *Virginia Journal of Science*, Vol. 2, No. 1, New Series, 1951
16. Harschbarger, Boyd and Davis, Lyle L., "Latinized Rectangular Lattices," *Biometrics*, Vol. 8, No. 1, March 1952, pp. 73-84
17. Hendricks, Walter A., Mathematics of Sampling," (Special Technical Bulletin, Feb. 1948), Virginia Agricultural Experiment Station, Blacksburg, Virginia
18. Hempthorne, Oscar, *Design and Analysis of Experiments*, John Wiley & Sons, Inc., New York, 1952
19. Mood, Alexander, *Introduction to the Theory of Statistics*, McGraw-Hill Book Co., Inc., New York, 1950
20. Simon, Leslie, E., "On the Relation of Instrumentation to Quality Control" *Instruments*, Vol. 19, Nov. 1946, pp. 654-56
21. Weatherburn, C. E., *Mathematical Statistics*, Cambridge University Press, 1947.

* For a discussion of precision instrumentation, see papers by Grubbs (Ref. 12) and Simon (Ref. 20)

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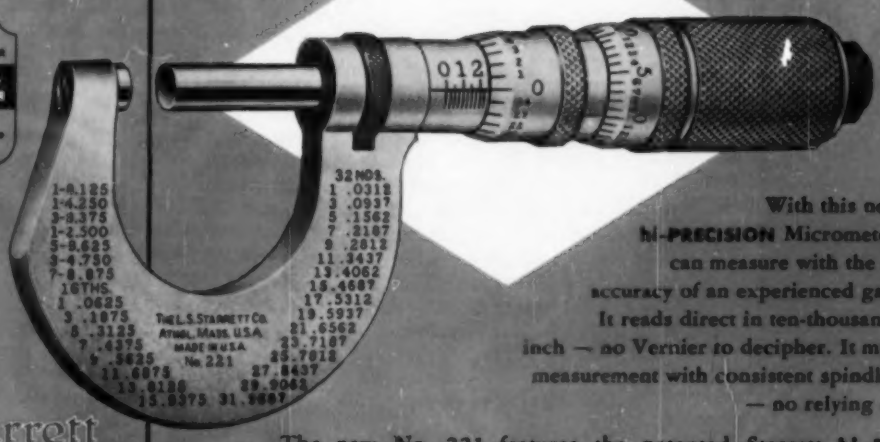

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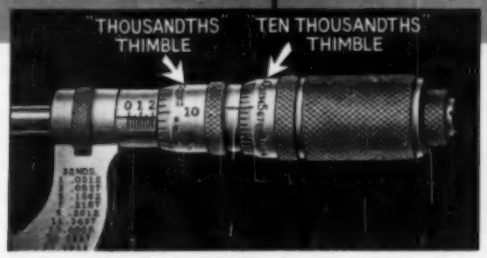

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Bibliography

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9220 Old Bonhomme Road
St. Louis 24, Mo.

APPLICATION—CHEMICAL INDUSTRY

AN APPLICATION OF STATISTICS TO REACTION KINETICS, W. McBride and D. S. Villars (Analytical Chemistry—v. 26, n. 5, May 1954)

The authors suggest the use of weighting of the dependent variable when using a curvilinear relationship as a linear after converting to a logarithmic scale. It is not sufficient merely to convert to logs as this nullifies the assumption that each observation has equal experimental error. As an example, the variation ratio to absolute temperature is given.

STATISTICS ON THE MOVE (Chemical Engineering—v. 60, n. 12, Dec. 1953, p. 118)

The increased use of statistical methods in the process industries is discussed. Several companies are listed as examples of the increased use of these techniques. Some of the arrangements indicated for design of experiments, factorial design and quality control are noted. Very brief definitions are presented for some basic statistical conceptions. Some of the difficulties encountered in introducing statistical methods are presented. The principal problem indicated is one of human relations rather than the mathematical and engineering aspects.

APPLICATION—ELECTRICAL INDUSTRY

APPLICATION OF QUALITY CONTROL REQUIREMENTS IN MANUFACTURE OF COMPONENTS FOR COAXIAL CARRIER SYSTEM, by A. T. Chapman ASME—Trans.—v. 76, n. 4, May 1954, p. 585)

Quality Control procedures are applied to amplifier and transmission electronic components of Bell System's long distance cable installation. Statistical techniques are used with such items as indicators, capacitators and coils in the factories providing material to the Bell System. Illustrations of factory applications are given.

APPLICATION—MISCELLANEOUS

STATISTICAL CONTROLS LENGTHEN LIFE OF CUTTING TOOLS, by W. H. Seacord and F. L. Helmel, Mechanical Engineering Research Division, International Harvester Co. (SAE Journal—v. 62, n. 5, May 1954, p. 55)

This article briefly indicates the advantages of using statistical controls on tooling items such as gear hobs, milling cutters, broaches, form tools, etc. The exact statistical controls are not indicated, other than performance record cards.

CONTROL CHARTS

CONTROLLING PRODUCTION QUALITY BY NUMBER OF PARTS DEFECTIVE, by Martin H. Saltz, Quality Control Engineer, Hughes Aircraft Co., Culver City, Calif.
(The Tool Engineer—v. XXXII, n. 5, May 1954, p. 47)

The fraction defective chart and the binomial equation upon which it is based is presented. Considerable basic theory is included. An interesting nomograph for computing p chart control limits is given. An example of the use of the p chart with sampling inspection is presented.

CHARTS USED FOR CONTROLLING QUALITY OF ASSEMBLIES, by Martin H. Saltz, Quality Control Engineer, Hughes Aircraft Co., Culver City, Calif.
(The Tool Engineer—v. XXXIII, n. 1, July 1954, p. 74)

The c chart theory and use is discussed. Examples of its application are presented. The c chart theory for demerits is also developed and formula provided. The "defects per unit" and "weighted defects per unit" approach are also included.

Selected references in the Bibliography of *Industrial Quality Control* are obtained from the following sources:

The International Statistical Institute, *International Journal of Abstracts on Statistical Methods in Industry.*

The Chemical Division, ASQC.

The Statistical Committee, TAPPI.

CHI SQUARE

TOO GOOD TO BE TRUE, by Alan Stuart
(Applied Statistics—v. 3, n. 1, Mar. 1954)

The question of using a χ^2 test and rejecting the null hypothesis on the basis of some small value of χ^2 is discussed. The use of the one or two tailed critical rejection regions is discussed.

ANALYSIS OF VARIANCE

EVALUATION OF SEVERAL SETS OF CONSTANTS AND SEVERAL SOURCES OF VARIABILITY, by V. W. Vaurio and Cuthbert Daniel
(Chemical Engineering Progress—v. 50, n. 2, Feb. 1954, p. 81)

The problem of setting up a basic model to evaluate the effect of several constants and sources of variability is discussed. A simplified example is presented. The actual application to an investigation of tin-plate corrosion resistance at United States Steel is discussed. The tables set up and the statistics necessary to conclude the experiment are presented. The interpretation of the Analysis of Variance statistics is indicated.

STATISTICAL DESIGN, by W. J. Youden, Bureau of Standards, Washington, D. C.
(Industrial and Engineering Chemistry—v. 46, n. 6, June 1954, p. 115A)

This article discusses some of the general problems in setting up and analyzing experimental proj-

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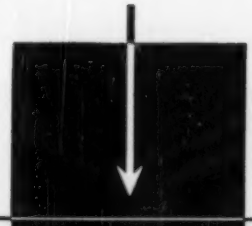

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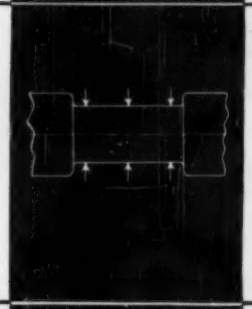

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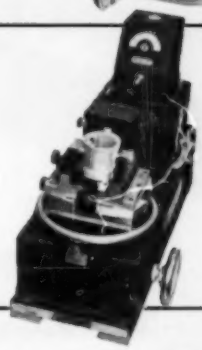

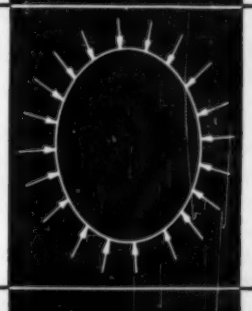

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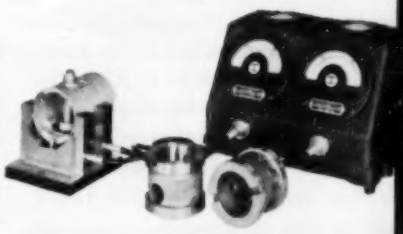

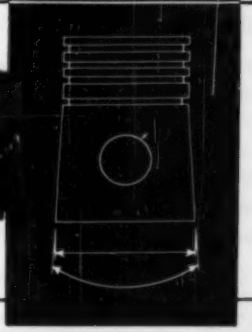

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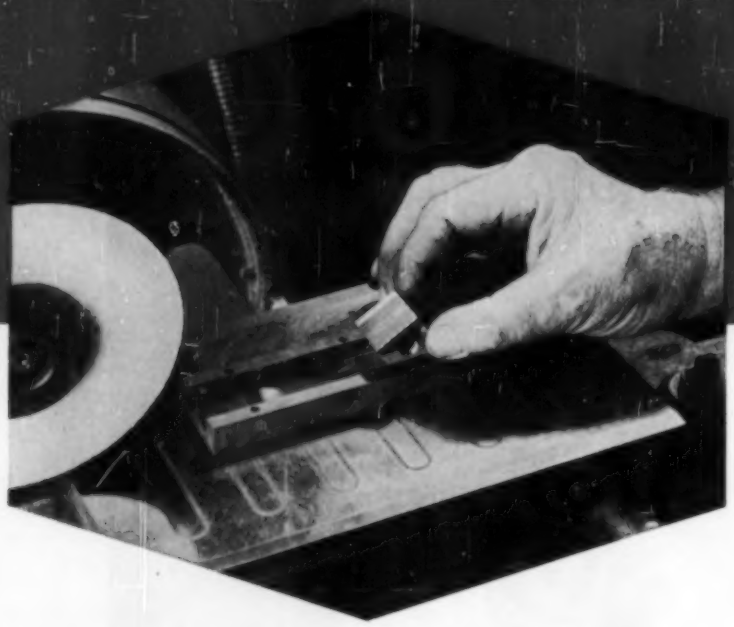

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ects. The use of statistical arrangements to analyze the effects of different factors is discussed. The Latin square is specifically considered.

ENGINEERING AND EXPERIMENTS

A SYSTEMATIC METHOD FOR ANALYZING AND ASSIGNING PRACTICAL TOLERANCES, by E. T. Fortini, Computer Dept., Raytheon Mfg. Co., Waltham, Mass.)

(Machine Design—v. 26, n. 8, Aug. 1954, p. 117)

This article stresses the importance of selecting tolerances to provide the desired quality at an economic cost. The article suggests 'instead of making the tolerance fit the design, make the design fit the tolerance." The process of analysis presented is called "dimensional analysis" or "dimension study." Considerable detail is presented, much of it based on the addition of subtolerances to get an over-all tolerance. The article states that "Wherever possible the design should make use of statistical methods in order to evaluate the effect of tolerances as they will most probably happen." A reference is given for further information on this aspect of the problem but is not specifically applied to the examples given. The use of natural tolerances determined by statistical methods as a working basis is also suggested.

DRAFTING PRACTICE ON THRESHOLD OF MORE REALISTIC TOLERANCING, by P. G. Belitsos, General Electric Co.

SAE Journal,—v. 62, n. 8, Aug. 1954, p. 17)

This article discusses a British system of tolerancing based on three basic principles. This system is being proposed by the SAE Joint Aeronautical and Automotive Drafting Committee. Greater interchangeability and economy of tolerancing are claimed for these approaches. These are primarily related to the geometry of location positioning and assembly relationships.

ASSIGNING TOLERANCES FOR MAXIMUM ECONOMY, by Eugene W. Pike and Thomas R. Silverberg, Radar and Communica-

tions Div., Raytheon Mfg. Co., Waltham, Mass.
(Machine Design—v. 25, n. 9, Sept. 1953, p. 139)

This article discusses in some detail the problem of assigning tolerances, particularly to assemblies, to assure the lowest cost within the needs of the product. Basic statistical formulas are developed for this problem and the theoretical considerations are presented in some detail. The assignment of tolerances are presented as a special example of the "search problem" in a specific chain situation. The applications of this theory are presented in terms of several design problems. The mathematics and analysis is illustrated in several tables and charts.

MANAGEMENT AND PERSONNEL, GENERAL

STATISTICAL CONTROLS AIDS MANAGEMENT—BY EXCEPTION, by Robert Kirk Mueller
(N.A.C.A. Bulletin—v. 34, n. 10, June 1953)

This article describes the basic principles of the normal distribution and briefly the use of this principle in control charts to help analyze business patterns and out-of-control conditions. It is a general article with some examples of applications.

USE OF SAMPLES IN AUDITING, by N. Williams
(Applied Statistics—v. 2, n. 3, Nov. 1953, p. 180)

The application of sampling to auditing is discussed. Mr. Williams points out that sampling can be used on cases of errors in the accumulation of numbers. To do this, he determines the sample size from a predetermined allowable standard error.

QUALITY CONTROL BY INFILTRATION, by H. J. Jacobson, Grand Sheet Metal Products Co., Melrose Park, Illinois
(Tooling and Production—v. XX, n. 6, Sept. 1954, p. 12)

The most important problem facing the Quality Control Engineer is basically the "selling" of Quality Control to management, foremen, and the workers. This article discusses some of the problems and approaches to winning the confidence and cooperation of industrial personnel.

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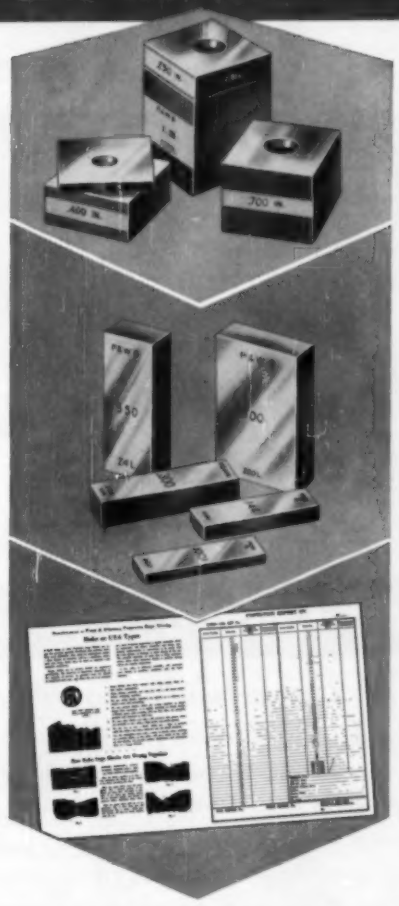

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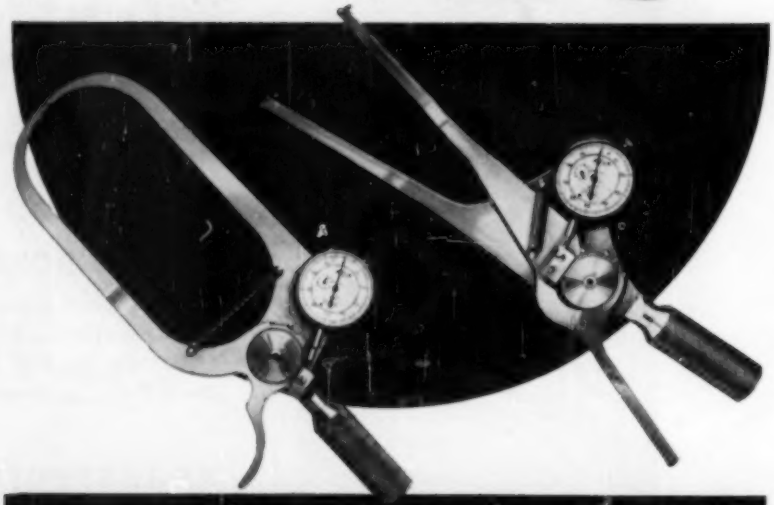

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INDUSTRIAL MANAGEMENT

USING STATISTICAL TOOLS TO KEEP COSTS CURRENT, by Clair W. Bendel

(N.A.C.A. Bulletin—v. 34, no. 10, June 1953)

The article clearly describes the use of statistical methods in adjusting standard costs in a farm machinery manufacturing company. A three part procedure was adopted to obtain current and predicted costs as follows:

(1) The stratification of material costs
(2) Sampling to secure an accurate average cost at reasonable cost.
(3) Indexes of current (or future) costs to standard

The use of these three principles has also been applied in setting new standard costs. The author states that the methods adopted have reduced the time for preparing reports and determining costs by thousands of manhours.

THE USE OF STATISTICS IN ACCOUNTING CONTROL, by Robert M. Trueblood

(N.A.C.A. Bulletin—v. 34, n. 11, July 1953)

The author urges the combined efforts of statisticians and accountants in adopting statistical methods to accounting and auditing. He briefly describes the application of statistical methods to (1) Labor Efficiency Reports, (2) Dollar Value "LIFO" Indexes, (3) Aging of Accounts Receivable, and (4) Confirmation of Accounts Receivable. The value of a clear presentation of data by charting and the use of sampling techniques in auditing is emphasized.

AN INTRODUCTION TO STATISTICAL COST CONTROL, by L. Wheaton Smith, Jr.

(N.A.C.A. Bulletin—v. 34, n. 4, Dec. 1952)

An article suggesting the need for a statistical approach in the analysis of costs. The author suggests the use of control limits on either the total cost or component costs of highly variable operations. In conclusion, he states that the procedures which would be used in such a system have not been developed, but that this would be a fruitful area for research and development.

WORK SAMPLING STUDIES: GUIDES TO ANALYSIS AND ACCURACY CRITERIA, by B. L. L. Sammet

INDUSTRIAL QUALITY CONTROL

(The Journal of Industrial Engineering—v. V, n. 4, July 1954, p. 9)

Statistics is applied to the industrial engineering problem of determining the number of observations and the effect of sample size on error in work sampling studies. Charts for the number of observations for any risks of error are presented.

MATHEMATICAL METHODS IN MANAGEMENT PROGRAMMING, by Melvin E. Salveson, Management Sciences Research Project, University of California, and Logistics Research Project, George Washington University.

This article discusses in some detail the development of a mathematical model for the problem of production control. This is illustrated in some detail through discussion and a graphical presentation of the operations research methods employed. The basic models presented permit consideration of such problems as:

A. Programming Over Time
B. Material Allocation
C. Alternative Production Methods
D. Inventory Costs
E. Economic Lot Size
F. Fixed Sales Requirements
G. Cost Minimization
H. Profit Accounting and Marginal Costs

MISCELLANEOUS

CONTROLLING CLERICAL ERRORS
(American Business—v. 24, n. 2, Feb. 1954)

A brief discussion on the success of sampling techniques in checking clerical work at Aldens, United Air Lines, Inc., and Standard Register Company. The article does not discuss the actual sampling plans.

CONTROLLING QUALITY
(Production—v. 34, n. 3, Sept. 1954, p. 73)

A round table discussion of functional testing, the application of quality control techniques, and the economics of inspection.

QUALITY CONTROL BEYOND THE SHIPPING DOCK, by F. J. Hiday, Quality Control Manager, American Kitchens
(Production—v. 34, n. 4, Oct. 1954, p. 87)

This article discusses a program undertaken to study causes of damage in shipment and the institution of corrective measures. Not Statistical Quality Control.

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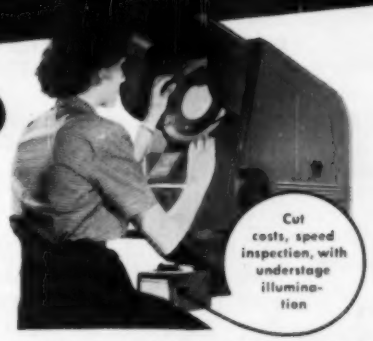

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Quality Control
INSTRUMENTS

SAMPLING PLANS & RELATED TOPICS

PRINCIPLES OF SAMPLING, by W. G. Cochran, F. Mosteller and J. W. Tukey

(American Statistical Association, Journal—v. 49, n. 265, Mar. 1954, p. 13)

A general article discussing the principles of sampling. The use of the probability sample is discussed as well as methods of avoiding systematic errors in sampling

SAMPLING PLANS REDUCE INSPECTION TIME, by Martin H. Saltz, Quality Control Engineer, Hughes Aircraft Co., Culver City, Calif.

(The Tool Engineer—v. XXXIII, n. 3, Sept. 1953, p. 45)

The basic conceptions of sampling are introduced with particular emphasis on MIL-STD-105A. The use of this table and its application is presented and illustrated with numerous charts and tables.

OPERATIONS RESEARCH

THE PROBLEM OF TESTING FOR THE FRACTION OF DEFECTIVES, by J. V. Breakwell

OPERATIONS ANALYSIS IN THE UNITED STATES AIR FORCE, by Leroy A. Brothers

PRIORITY ASSIGNMENT IN WAITING LINE PROBLEMS, by Alan Cobham

(Journal of the Operations Research Society of America—v. 2, n. 1, Feb. 1954)

OPTIMUM PREVENTIVE SAMPLING, by P. Whittle

TRAFFIC DELAYS AT TOLL BOOTHS, by Leslie C. Edie

THE INFLUENCE OF SERVICING TIMES IN QUEUING PROCESSES, by Donald P. Gaver

(Journal of the Operations Research Society of America—v. 2, n. 2, May 1954)

THREATS TO THE GROWTH OF OPERATIONS RESEARCH IN BUSINESS AND INDUSTRY, by Robert F. Rinehart

OBSERVATIONS ON OPERATIONS RESEARCH, by M. L. Hurni

THE CONTROL OF INVENTORY AND PRODUCTION RATES—A SURVEY, by Herbert A. Simon and Charles C. Holt

THE EFFECT OF RELIABILITY OF "SUPERVISORY" EQUIPMENT ON THE ACCURACY OF A 'SUPERVISED" SYSTEM, by Alexander W. Boldyreff

INFORMATION THEORY AND MAN-MACHINE SYSTEMS, by Gilbert K. Krulee

(Journal of the Operations Research Society of America—v. 2, n. 3, Aug. 1954)

Problems Department

PAUL C. CLIFFORD and THOMAS A. BUDNE, *Co-editors*

Problems for solution, and correspondence concerning material, published in this department, should be addressed to:
Thomas A. Budne
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THAT'S OUR BOY

Once again, our illustrious Problems Department editor, Paul Clifford, has been called upon to go abroad to give assistance in developing and furthering the use of Statistical Quality Control in the industries of other countries. Details of this assignment are reported on page 3 of this issue, but for the record in this department, we note that he will be gone a full year on an itinerary that includes all the free countries of Europe, with Turkey thrown in for good measure. We send with Paul our best wishes for a successful and enjoyable trip, and shall look forward to publishing occasional memoranda concerning his travels, with maybe a European problem thrown in here and there.

WHO'S GOT THE PROBLEMS NOW?

Under Paul's supervision, this department has been ably conducted in the past. During his absence we shall try to carry on the spirit and tradition which the Senior Editor has established for it.

We continue to want questions on the management and the functional operation of a quality control program, and the economics of quality control, as well as problems involving statistical methods. The continued success of this column remains a community activity. Some of you have the problems and some of you have the answers. Let's get them together—*here!* And if occasionally we can't find somebody with the answers—we'll just call that the Editors' problem.

The cupboard isn't completely bare, but it did get thinned down over the summer. So sit down and write us those problems you keep talking about!

Here are two new ones:

Problem 11. Suggested by J. H. Fairfield, Montreal, Canada.

If inspection is done on a random sampling basis, the exact process average defective cannot be determined exactly, except that we can find the upper and lower confidence limits within which the process average will lie with a known degree of confidence. The problem of estimating process levels arises very frequently in our inspection work.

The approach to the same type of problem when a continuous inspection plan is used, is not so simple. The type of continuous plan we are using is as follows: At the outset, inspection is carried out on a 100-percent basis, each unit is inspected as it comes off the end of the line. As soon as a predetermined quantity of n units have been inspected and passed, 100-percent inspection ceases, and the inspector starts taking random units at a rate f, where f is some fraction between zero and one. If f is 1/10, he inspects every tenth unit. He continues sampling at this rate as long as no defective

unit appears. If and when a defective unit does appear, 100-percent inspection is resumed until a complete run of n successive good units are again passed.

Each plan will be completely determined by the two parameters, n and f, and any given combination of n and f will give a certain A.O.Q.L. provided that all defective units found in the inspection process are removed from the lot and replaced with good products.

At the end of the lot, the inspector's report gives the following quantities.

N — number of units produced.
n_1 — number of units inspected on a 100-percent basis.
n_2 — number of units inspected at a rate f.
d_1 — number of defective units found in the n_1 units.
d_2 — number of defective units found in the n_2 units.

From these figures, can we calculate the 95-percent confidence limits for the fraction defective of the entire lot, or for the process average? (Ed. note: The sampling plan described above was developed by H. F. Dodge, "A Sampling Plan for Continuous Production", *Annals of Mathematical Statistics*, Vol 14, No. 3, Sept. 1943, pp. 264-279; *also, Industrial Quality Control*, Vol. IV, No. 3, Nov. 1947, pp. 5-9.)

Problem 12. Suggested by Robert Laster, Metropolitan Section.

In using the F tables for comparing two variances, I have noted that for any specified number of degrees of freedom, n_2, in the denominator, the values of F decrease for increasing degrees of freedom, n_1, in the numerator; *except* for the cases n_2 equals 1 or 2. In these latter two cases F increase as n_1 increases. Is there some possible intuitive, rather than mathematical explanation for this?

Problem 7. Suggested solutions.

Somewhere along the line, this problem, which appeared in the July 1952 issue, became lost. "If u and v are normally distributed variables, what are the distributions of u/v, uv and u^n?" Several suggested sets of solutions were received. The most direct and comprehensive of these came from Dr. Leo A. Aroian, Culver City, California. He wrote:

"The distribution of the quotient and product of two normally distributed variables was the subject of a paper by Prof. C. C. Craig, "On Frequency Distributions of the Quotient and Product of Two Statistical Variables," Amer. Math. Monthly, Vol. XLIX, No. 1, Jan. 1942, pp. 24-32, in which references up to 1942 are included.

"For the quotient u/v of a bivariate normal probability function with means m_u, m_v, standard deviations σ_u, σ_v, and coefficient of correlation ρ, the main result by Geary, states: If m_v/σ_v is large and m_v is positive then the quantity

$$\frac{m_v Z - m_u}{(\sigma_u^2 - 2\rho\sigma_u\sigma_v Z + \sigma_v^2 Z^2)^{1/2}}$$

where $Z = u/v$, is approximately normally distributed with zero mean and unit variance. The exact distribution of u/v is discussed in Craig's paper.

"For the product $w = uv$, Craig in the same paper gives exact results in the form of an infinite series. However, if either m_u/σ_u, m_v/σ_v or both are large and positive, the writer has shown that the product, w, is distributed normally with mean of

$$w = m_u m_v + \rho\,\sigma_u\sigma_v$$

and variance of

$$w = m_u^2\sigma_v^2 + m_v^2\sigma_u^2 + \sigma_u^2\sigma_v^2 + 2\rho m_u m_v \sigma_u\sigma_v + \rho^2\sigma_u^2\sigma_v^2$$

This paper, "The Probability Function of the Product of Two Normally Distributed Variables," was published in the Annals of Math. Stat., Vol. 18, No. 2, June 1947, pp. 265-271 and contains more detailed information and relevant references to that date.

"This brings us to the final part of the question, the distribution of u^n for n equal to positive and negative integers. Exactly how much was desired is not clear from the question, although presumably it was intended that n be a positive integer. Very little is given explicitly in the literature, although the methods of proof are elementary. Most of the specific results are new. In the succeeding theorems it is assumed that u is distributed normally with mean m and standard deviation σ, and we let $Z = u^n$.

"Theorem I: Let n be an even integer. The probability function P_Z is given by

$$P_Z = \frac{1}{|n|\sigma}\sqrt{\frac{2}{\pi}}\;\frac{e^{-\frac{Z^{2/n}+m^2}{2\sigma^2}}}{Z^{1-1/n}}\cosh\left(\frac{mZ^{1/n}}{\sigma^2}\right), \qquad 0 \leqq Z < \infty.$$

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The special case n = 2 is of interest. In this case

$$P_z = \frac{1}{\sqrt{2\pi}} \frac{e^{-\frac{Z^2+m^2}{2\sigma^2}}}{\sigma\sqrt{Z}} \cosh\left(\frac{m\sqrt{Z}}{\sigma^2}\right), \qquad 0 \leqq Z < \infty.$$

Now as $m/\sigma \to \infty$, it is interesting to note that Z is distributed normally with mean $= \sigma^2 + m^2$, and variance $= 2\sigma^2(\sigma^2+2m^2)$.

"Theorem II: Let n be an odd integer. The probability function of Z is given by

$$P_z = \frac{1}{|n|\sqrt{2\pi}} \frac{e^{-\frac{\sigma Z^{1/n}-m}{2\sigma^2}}}{\sigma Z^{1-1/n}}, \qquad -\infty < Z < \infty.$$

A case of special interest here is n = 3.

$$P_z = \frac{1}{3\sqrt{2\pi}} \frac{e^{-\frac{(Z^{1/3}-m)^2}{2\sigma^2}}}{\sigma Z^{2/3}}, \qquad -\infty < Z < \infty.$$

Again for $m/\sigma \to \infty$ we see that Z is distributed normally with mean equal to $3\sigma^2 m + m^3$ and variance equal to $3\sigma^2\ (5\sigma^4 + 12\sigma^2m^2 + 3m^4)$."

Practical Aids

ELLIS R. OTT, *Editor*

Send your "Practical Aid" contribution to:
Dr. Ellis R. Ott
Rutgers University
77 Hamilton Street
New Brunswick, N. J.

Determination of Process Capability

FRANK M. GRYNA, JR.

University College, Rutgers University, New Brunswick, N. J.

The average foreman regards a "standard deviation" with something less than passion. This can be a problem.

An important industrial question is "What is the minimum tolerance this process can hold?" Simple quality control techniques provide a sound basis for determining this "process capability" figure.

The textbooks suggest that a control chart be run and σ' calculated (after assignable causes are eliminated). On the assumption of a normal population, the process capability is then computed to be $\pm 3\sigma'$ or $6\sigma'$. In applying this method in the factory, it may have to be explained to production people unfamiliar with statistics. Arise the dilemma! After discussing the control chart with him, we may have to convince a foreman that the process capability is essentially "6 standard deviations". Even after explanation, the concept of a standard deviation is still mystifying to a foreman—even though he may not admit this.

This situation is aggravated because the foreman has his own method of determining process capability. He simply measures a number of pieces and finds the difference between the largest and smallest. That difference is process capability. Interestingly enough, it is possible to adapt the foreman's method with statistical validity. Dr. S. S. Wilkes[1] has developed some theory

[1]Wilks, S. S., "Statistical Prediction with Special Reference to the Problem of Tolerance Limits," *The Annals of Mathematical Statistics*, Vol. 13, No. 4, 1942, pp. 400-409.

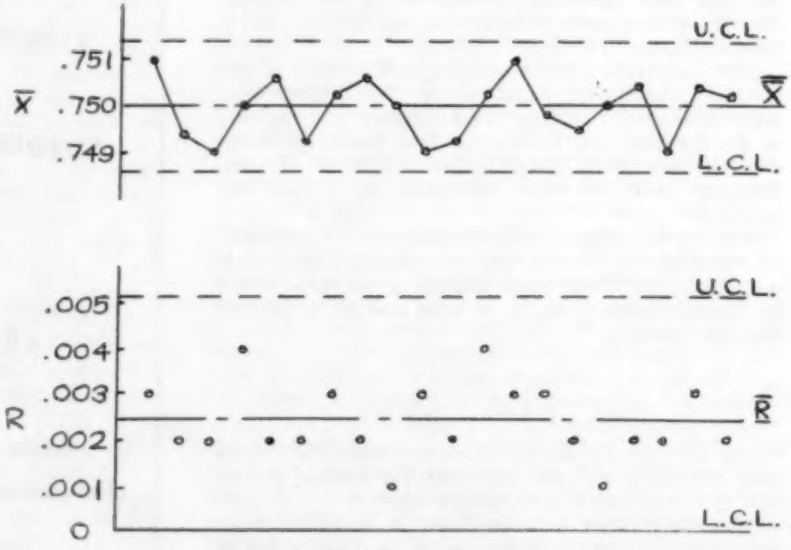

Figure 1—Control Chart for Average and Range.

that makes this possible. It can be stated as follows:

> If we inspect a sample and find the largest and smallest pieces, then the probability is 0.99 that at least a stated percentage (listed in a table) of future long run production will lie between the largest and smallest values found in the original sample. An important condition is that the process be in statistical control.

Let's consider an example. Suppose we are using a centerless grinder to cut a diameter. A control chart analysis is made to test for uniform variation. Samples are inspected and the control chart of readings is plotted (Fig. 1). Since the process shows control, we may enter the world of prophecy. To predict the process capability, simply find the minimum and maximum values among the original pieces. Table 1 furnishes the figures necessary for the prediction. (Note the precarious assurance connected with very small sample sizes—even assuming control). For example, suppose we inspected 20 samples of five each or 100 individual pieces for the control chart data. Further, assume that the extremes were 0.748″ and 0.754″. From Table 1, we can now say (with a probability of 0.99) that at least 93.5 percent of future production will lie between 0.748″ and 0.754″—assuming control is maintained. In more common terms, the process capability is, to a high degree of certainty, $0.754 - 0.748 = 0.006 \pm 0.003$″.

Table 1*—"Proportion of Production from a Controlled Process Having a 99% Probability of Lying within the Observed Range of a Sample of n".

Total number of individual pieces	% within limits
10	49.6
50	87.4
100	93.5
200	96.6
300	97.8
400	98.3
500	98.7

*Derived in part from formulas in Reference 1.

Note: In the preceding discussion, we have emphasized the need for a control chart. If we are to predict process capability (no matter what method is employed), it is essential to recognize that a process in statistical control is a necessity. First, the control chart will tell whether or not the process is operating uniformly. To assume uniform operation without first checking with a control chart is optimism based on a foundation of straw! Secondly, any measure of capability (whether of a process or a human being) must be referred to a given set of given conditions that we have reason to believe will repeat in the future.

Consider the ball player. What do we mean when we say that a player is capable of batting .300? We mean simply that the player is capable of averaging 300 base hits for every 1,000 times at bat. Suppose that during one season, the player developed an annoying stomach ailment and finished the season with a batting average of only .250. We originally said he was capable of batting .300. It would seem, then, that the capability figure of .300 is

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in error. However, we will immediately agree that the .250 batting average is not representative of his true ability. Why? Because he was not playing under his normal operating conditions (i.e. good health). In denoting the capability of the player as .300, we inherently referred to "a given set of conditions that we have reason to believe will repeat in the future."

In precisely the same manner, we must refer process capability to a set of conditions which will repeat in the future. The reference conditions for a process is also "good health." Good health for a process (or a ballplayer) is simply a set of conditions that produce uniform performance—meaning a controlled process. We now have a set of conditions to serve as a reference point, but will these conditions repeat in the future? The control chart will tell us.

Finally, a word of practicality. Economical or other considerations sometimes indicate that the cost of running a control chart is not justified. The above discussion points out the uncertainty of a process capability figure estimated without a control chart. In this case, the consideration must be whether or not the cost of the control chart study is balanced by the added responsibility of the estimate.

Local Section News

". . . BUT NOT FORGOTTEN"

ALBANY The new season was introduced with a "Management Night" on Sept. 23 at the Crossroads, Latham, N. Y. Our problem session at 4:30 p.m., a regular feature of each meeting, was based on a management problem in setting up adequate and proper records for a batch-type process.

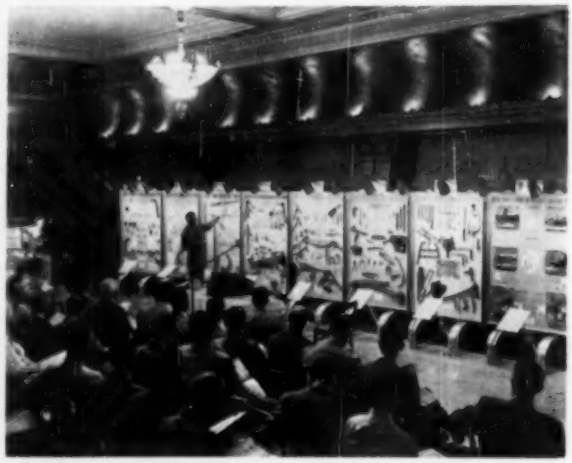
Following the dinner, as a new innovation, we had C. D. Ferris as the first in a series of "Coffee Speakers." The main speaker of the evening, Dr. A. V. Feigenbaum, Manager of Quality Control and Cost Reduction for the General Electric Mfg. Services Div., gave an excellent talk on "Quality Control as a Management Method," stressing the point that the modern concept of quality control is much broader than just the application of statistical quality control methods to inspection and production.

ALBUQUERQUE Dale L. Lobsinger, United Airlines, spoke to the Albuquerque Section meeting at the University of New Mexico on Sept. 9. His subject was "Some Administrative Uses of SQC in United Airlines."

BUZZARDS BAY This section presented a panel discussion "What Is Quality Control in New Bedford Industry?" over radio station WNBH at 8:00 p.m. on Sunday, August 22.

Members participating in the panel were E. S. Rudnick, Wamsutta Mills, Rene L'Heureux, Aerovox Corp., W. H. S. Preece, Revere Copper and Brass, K. V. Chace, Hathaway Mfg. Co., R. E. Cooper, Bradford Durfee Technical Institute, and Russell St. Pierre, Acushnet Process Co. The program was planned and directed by Mary Lindenberg, Kalco Textile Co., who reports that a tape-recording of the program was made and is available to other sections on request.

CHICAGO The first meeting of this section was held on Sept. 15 at the Furniture Club and covered the general topic "Problems in Measurement and Testing." The first part of the afternoon meeting featured a talk by Hamilton Migel, vice president in charge of research and engineering, Magnaflux Corp., on non-destructive testing methods. At the second part E. O. Krueger, Abbott Laboratories, discussed "Process Controls in the Pharmaceutical Industry."



Following the social hour and dinner was presented the program "Civilization Through Tools." This program consisted of an elaborate display which was prepared under the direction of the Wilkie Foundation and presented by the Do-All Company. The display was described in a talk by C. G. Schelly, Managing Director of the Wilkie Foundation.

The first session of the advanced educational program was held on Tuesday, Sept. 21, at the Wahl-Henius Institute. The meetings are being held every Tuesday evening for a sixteen-week period and will follow closely material covered in W. J. Youden's book *Statistics for Chemists*. The advanced series is under the direction of Marjorie Sutherland. She has planned a lecture for the first part of each three-hour session; the second part will be devoted to presentations by the class members of examples from the files of their companies and showing the actual application of the theory under study.

CLEVELAND The Cleveland Section held its first meeting of the 1954-55 series on Oct. 1. R. E. Lewis, president of Argus Camara Co., spoke to the well-attended meeting on the applications of quality control at Argus. Following his talk the group watched a movie on the manufacture of precision cameras.

DELAWARE At the end of September the executive committee of this section held its fourth meeting to discuss activities and plans for the 1954-55 season.

HARRISBURG The first meeting of the 1954-55 season was held at the Thompson Products plant and chalked up a whopping attendance of 156 members and guests. W. H. Johnson, plant manager, welcomed the group. The program consisted of a tour of the plant followed by dinner and a QC skit "Sampling Inspection" put on by the members of the Allentown-Bethlehem Section under the direction of Miss Bonnie Small. Among the guests were W. L. Gillette, chairman of the Allentown-Bethlehem Section and T. G. Gregory, chairman of the Danville-Sunbury Section.

HUNTSVILLE Verne H. Reckmeyer, Thiokol Chemical Corp., spoke at the September meeting of the Huntsville Section. The subject of his speech was "Frequency Distributions—How to Use Them." Mr. Reckmeyer spoke on how to develop a background for using frequency distributions in studying industrial processes. As in other scientific fields, frequency distributions assume typical, recognizable patterns. Mr. Reckmeyer used actual case histories to illustrate what can be learned about various industrial processes by the use of frequency distributions.

INDIANAPOLIS On Sept. 21, Allison Div. of General Motors Corp. was host to the Indianapolis Section for the section's kick-off meeting. The program began with a visit to the Allison Powerama which started at 2:00 p.m. The dinner was held in the Allison Cafeteria at 6:00 p.m. and the after dinner speaker was L. Gray Burdin, Dean of Men, Butler University. He spoke on the subject "The Definition of Leadership." The program was completed with a second tour of the Allison Powerama for those who could not go in the afternoon. Over 300 members and guests attended the meeting.

In connection with its sub-section development program the Indianapolis Section sponsored organizational meetings for the Bedford, Columbus and Richmond subsections. The Bedford meeting was held on Sept. 16 with 13 members of the Indianapolis Section and 28 guests attending the meeting; the Columbus meeting on Sept. 30 with 7 members and 17 guests; and the Richmond meeting on Sept. 29 with 12 members and 13 guests. At each of these meetings the Indianapolis Section members presented the program which consisted of the history and purpose of ASQC and some fundamen-

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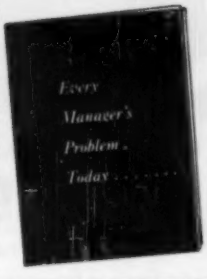

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tals and examples of quality control. Both the Columbus and Richmond sub-sections are presenting basic training programs in SQC, the Richmond program being under the direction of Carl Hoover, Perfect Circle Corp.

INDIANAPOLIS
Lafayette Sub-Section On Sept. 28 the Lafayette sub-section held its first meeting of the season with Carl Hoover, Perfect Circle Corp., as the speaker.

KANSAS CITY The Kansas City Section opened its fall season with a dinner meeting at the American Legion Building on Sept. 8, at 7:00 p.m. Approximately 50 members and guests heard H. J. Jacobson's review of his subject "Quality Control by Infiltration." His many suggestions for applying quality control tools were illustrated by colored slides.

LINCOLN E. H. Robinson, Johnson and Johnson Co., presented an analysis of Sales Control using charting and statistical techniques to assist Production Control in ordering and processing materials in his company.

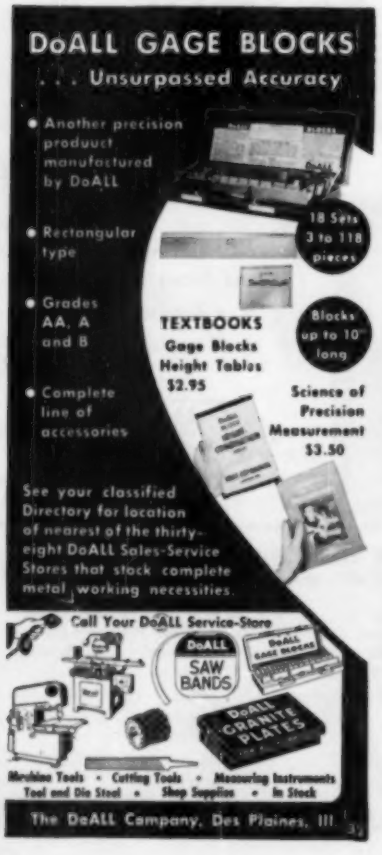
LOS ANGELES The new season started with a "bang" for the Los Angeles Section on Sept. 14 because the speakers included Harry G. Romig, International-Telemeter; Major Gen. Leslie Simon, Assistant Chief of Ordnance, Research and Development; Paul Rider, Mathematical Branch of the Aeronautical Research Laboratory.

The latter two men were unexpected, but very welcome guests. General Simon explained Army Ordnance's attitude on reliability and Dr. Romig expanded on his fine paper on "Quality Control in Industry."

MICHIGAN More than 600 persons were present at the luncheon of the Ninth Annual Forum of the Michigan Section to hear Harvey M. Mecker, Parke, Davis & Co., tell the group of the "Importance of Observation." This large group assembled at the University of Michigan had the opportunity of hearing any three of 12 nationally known speakers on various aspects of SQC. In addition to all this several industrial concerns presented large displays of SQC activities in their organizations.

MILWAUKEE On Sept. 20 the Milwaukee Section had its initial fall meeting at the Wisconsin Hotel. The attendance was excellent, so was the dinner, and the talk by J. F. Roberts, vice president of Allis Chalmers Co., was well received. His subject was "Value of Quality Control to Modern Industry."

MINNESOTA On Sept. 14 the Minnesota Section inaugurated its 54-55 program with a social evening at Bayport, Minn. The evening began with a tour of the Anderson Corp., which is one of the largest makers of window millwork in the world. Wives also went on the tour and joined members at the dinner which was held at the White Pine Inn. A. D. Hulings, vice president in charge of production at Anderson, told of company policy and operation at the dinner.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NEW HAVEN The first meeting of the 1954-55 season featured "Management Night," with P. A. Robert, I.B.M. Corp., as guest speaker, following a dinner which was enjoyed by all. Mr. Robert presented a certificate to the section for attaining third place in the 1953-54 competition for the Presidential Award for Section Management. The section feels that this was an outstanding showing since it has been chartered only since May of 1953.

RICHMOND The local sections of ASQC and American Chemical Society held a joint meeting Sept. 10 with 55 attending the dinner and 95 the meeting afterward. The following men—each being a member of both societies—were at the head table: C. W. Baber, Chairman ACS; E. T. Ellis, Chairman ASQC; J. G. Coli, Secretary ACS; and G. F. White, Jr., Secretary ASQC. Unfortunately Huricane Edna kept Dr. W. L. Gore of Wilmington, Del. from being able to attend and give his talk on "Design and Analysis of Experiments."

ST. LOUIS The first meeting of the new year was well attended. More than 60 percent of the total membership was present for the very interesting presentation of a case history by William A. Clark of the Monsanto Chemical Co., on the subject, "Improving Marketing Effectiveness Through Operations Research." The new year began with a social hour in the Chouteau House, St. Louis University, followed by a dinner meeting in the University cafeteria. The social hour has come to be one of the pleasant evening hours because it is then that our members, guests and friends can get together and hash over their current problems and of course it is always a nice time to make the acquaintance of new and prospective members.

The St. Louis Section is currently offering a course, "A Ten Session Training Course in Quality Control," which will run for ten consecutive Friday evenings, except Thanksgiving. This is being offered for the newcomers in the St. Louis area as well as a "refresher" for any of us who have just gotten into quality control techniques. The instructors for this course are Joseph Movshin, Paul Durham and Arnold Braun. You may recall that Joseph Movshin operated our Book Booth during the St. Louis Convention and Arnold Braun was our Secretary-Treasurer. This training program is being sponsored jointly by the Chamber of Commerce, the Industrial Bureau, and the local section, and announcements of the course are being sent out with the usual Chamber of Commerce publication.

SAN DIEGO At the Sept. 13 meeting Dave Archibald, program chairman, served as the panel moderator for the discussion "Quality Control Manager's Responsibility Through Purchasing To Vendors."

SCRANTON—WILKES-BARRE At the initial fall meeting, held on Sept. 16, J. L. Dolby, statistical methods section of General Electric Co., discussed "Planning Experiments in Engineering," emphasizing how a statistical approach could materially reduce various tests and experiments.

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SEATTLE The first meeting of the year was held at the Benjamin Franklin Hotel on Sept. 14. D. L. Dye, chief consumer representative of the Scott Paper Co., Everett, discussed "The Consumer Concept" with such absorbing interest that the large audience of members and guests gave him quite an ovation. This was our first address pertaining to the important area of consumer research and the relationship between worker attitudes and consumer-dictated quality standards. A business meeting was held after the coffee break.

SOUTH BEND—MISHAWAKA The first meeting of this newly organized section got off to a rousing start with approximately 70 members and guests in attendance. Special guests included the mayor of South Bend, the secretaries of the Association of Commerce in South Bend and Mishawaka, the executive secretary of the Committee of One Hundred, Dean of Mathematics of Notre Dame University, and the president of the ASQC. Mayor John A. Scott remarked that while Iron Curtain countries could equal the U.S. numerically in weapons, we can and must maintain our superiority in quality—quality of Man, Material and Spirit. R. S. Saddoris chose as his topic "A Better Way," saying that nothing is so good today but what a better way can be developed tomorrow.

SOUTHERN CONNECTICUT The Southern Connecticut Section showed the film "Modern Quality Control," produced by the Johns-Manville Corp. as a visual training aid for their quality control problems. The showing, which was well attended, took place on Sept. 27 in the Burroughs Public Library, Bridgeport, and preceded the start of an exhibit on Quality Control Methods in the Technology Department of the Library. A complete and well-commended Quality Control bibliography, prepared under the supervision of Mrs Mildred Glazer, head of the Technology Dept., was available for distribution. The Exhibit was open to all industry people without admission and illustrated how local manufacturers applied quality control to their products. Companies with displays were the Singer Sewing Machine Co., The Bullard Machine Tool Co., and The General Electric Co. Much favorable comment has been received indicating the continued worth of this public endeavor.

SOUTHERN TIER The Southern Tier Section returned to its former haunt, the Vestal American Legion Clubhouse for its first meeting of the new season on Sept. 13. The quantity and quality of the fare served offered convincing proof that the decision by the new officers to return to the legion was a wise one.

Paul A. Robert, IBM Corp. and ASQC vice-president, was the speaker. His subject, "What ASQC Can Do for You," was very interesting and highly enlightening for both old and new members alike.

STATE UNIVERSITY OF IOWA The SUI Section of ASQC held their September meeting at the W. A. Sheaffer Pen Co., Sept.

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24 and 25. A very complete application of SQC techniques was in evidence throughout the Sheaffer Plant and a very educational question and answer period lasted all Friday afternoon following the plant tour. On Saturday, Sept. 25, the first part of the forenoon was devoted to our usual Problems Clinic where each and every member can present any problems he has and have them answered to the best of the ability of the group in attendance. Prof. Gayle W. McElrath, University of Minnesota, gave the group an educational demonstration of the "Fundamentals of Industrial Significance Tests" during the second half of the forenoon.

SYRACUSE The Syracuse Section heard Ned Miles of the General Electric Co., Louisville, discuss "New Approach to Machine Tool Selection and Control," on Sept. 28. In conjunction with his talk, he also presented an interesting film strip and tape recording.

The Section in cooperation with Smith Technical High School recently began teaching three courses in applied quality control. These courses include "Applied Techniques of Elementary Quality Control," "Applications of Sampling Plans" and "Significance Testing." They are being taught by Hugh N. Wallace, F. L. Winne and Albert Edgar.

TORONTO Our initial fall meeting, Sept. 15, began with an introductory subject, "Basic Concepts of Quality Control." Dr. Brant Bonner, University of Western Ontario, implemented his topic with a unique board which displayed a Shewhart chart using beads to indicate the various plotted points. As the board was turned to its side the beads rolled together in their respective columns to form a histogram.

Inspection methods were well demonstrated with a special lighting fixture to detect defective fills in a brewery. A few eager members agitated unsuccessfully for a live demonstration. The membership was very pleased to greet a large number of guests and prospective members. Following the meeting the members journeyed to Barrie, north of Toronto, to view the Canadian General Electric Co., Barrie Works.

TRENTON On Sept. 10 F. C. Schulze, Hunter Spring Co., was the guest speaker of the first meeting of the 1954-55 season. He spoke on some of the practical applications of SQC in a spring wire industry. At the conclusion of the lecture a social get together was held and beer and pretzels were served.

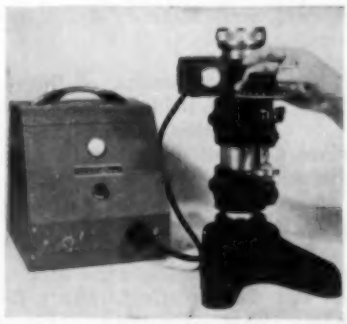
WASHINGTON The Sept. 24 meeting was held at National Canners Building and featured D. L. Lobsinger, United Air Lines, Inc., as the speaker. Mr. Lobsinger's subject was "Some Administrative Uses of Statistical Quality Control in United Air Lines." His examples of how the United Airlines used control charts to control ramp operations showed a unique use of quality control.

WESTERN MASSACHUSETTS The first meeting of the season was held Sept. 21, at Millers Restaurant, Springfield, Mass. Speaker was Axel U. Sternlof, American Steel and Wire

"the reference standard of industry"

CARSON-DICE ELECTRONIC

MICROMETERS



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Dice also manufactures a number of non-destructive testing and measuring instruments for Quality Control of metals and other materials. All are described in Bulletin No. 32.

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Co., who spoke on "Opinions Versus Facts in Industry." Mr. Sternlof proved very effectively and without using complicated techniques that things are not always what they appear to be.

"... CAST THEIR SHADOWS BEFORE"

CINCINNATI On Dec. 15, Leon Bass, General Electric Co., will speak to the section about "Quality Control in the Electronics Industry."

DELAWARE A record attendance is anticipated for the Dec. 2 meeting to hear J. M. Juran, management consultant, discuss "Management Control."

HARRISBURG The December meeting of the Harrisburg Section is to be held at the Caterpillar Tractor Co., York, Pa. Included in the program for this meeting will be a plant tour, dinner, and the guest speaker, L. C. Ankerbrand of the Caterpillar Co., whose subject will be "Managements Expectations."

HUNTSVILLE The Huntsville Section will have as its speaker for the December meeting, William E. Gibbons, Chief Quality Control Branch MPD, Redstone Arsenal, Huntsville, Ala. Mr. Gibbons will speak on "Practical Aids."

INDIANAPOLIS On Dec. 14, C. R. Hicks, Purdue University, will conduct a "What's Your Problem?" session, starting at 4:00 p.m. At 7:30 p.m., the group will be addressed by W. A. MacCrehan, of Bendix Radio, Baltimore, Md. He will speak on the subject "Quality Control in Action."

KANSAS CITY The Dec. 8 meeting of the Kansas City Section will consist of a plant tour. Fred Fitzgerald, Metallurgical, Inc., will conduct the tour of the plant which specializes in custom heat treating of metals.

MICHIGAN Of particular interest to the Michigan Section will be our speaker of Dec. 10, Ralph C. Schulz. Mr. Schulz's talk will be of direct concern to the group because his discussion will cover both the buyer and seller point of view of "Quality Control in an Automotive Parts Supplier Plant."

MILWAUKEE The Dec. 6 meeting will be held at the Miller Brewing Co. and will include a plant tour and buffet lunch. A panel discussion on Quality Control will be conducted by our section officers.

NEW HAVEN The fourth regular monthly meeting of the 1954-55 season will feature R. E. Heiland, Lehigh University, as guest speaker. Prof. Heiland's subject will be "Work Sampling." A dinner, open to section members and guests, will be held prior to the business meeting and lecture.

NORTHEASTERN INDIANA On Dec. 9 at 8:00 p.m., Jack Stolp, Assistant Sales Manager of Eastman Kodak Co., Rochester, N. Y., will speak to the section on the subject of "Inspection by Optical Projection." The meeting will be held at the Fort Wayne Chamber of Commerce.

SCRANTON—WILKES-BARRE William H. Cook, statistician in the Bureau of the Census, will give a talk on "Statistical Methods in Management and Application of SQC to Office Operations" at the Dec. 16 meeting.

SEATTLE Joseph Livers, Boeing Airplane Co., will elucidate on "Measuring Association with Rank Valued Data," at the Dec. 14 meeting. Visiting quality control men will find a friendly group of colleagues awaiting them on the second Tuesday of December, 7:30 p.m. in the Benjamin Franklin Hotel.

SOUTHERN TIER R. E. Bechhofer, professor of Industrial Engineering Administration at Cornell University, will address the Southern Tier Section at the Vestal American Legion Clubhouse on Dec. 7. His subject will be "Designing Experiments for Ranking Means."

SYRACUSE Frank L. Winne, Oberdorfer Foundry, will address the Section on Nov. 23. His subject will be "SQC in the Foundry."

TORONTO On Dec. 8, Wednesday evening, Julien Green, General Electric Co., Schenectady, N. Y., will speak to the section in Hamilton on "QC in Parts Manufacture."

TRENTON Dr. Gill, Dean of Rider College, Trenton, N. J., will be the guest speaker at a dinner meeting Dec. 3 at the Glendale Tavern. The subject of Dr. Gill's talk will be announced.

UNIVERSITY OF WESTERN ONTARIO The Kitchener Group of the University of Western Ontario Section will meet on Dec. 1. The speaker, Allin P. Deacon, Quality Control Consultant, will discuss "Some Methods of Quality Control."

WESTERN MASSACHUSETTS Second meeting of this season will be held on Nov. 23, at Rovellis Restaurant in Springfield. C. A. Bicking, office Chief of Ordnance, Washington, will speak on statistical quality control applications in the chemical industry. Dinner at 6:00 p.m. with technical meeting to follow at 8:00 p.m.

WICHITA The December meeting of the Wichita Section will feature Capt. Henry Simon, Headquarters, AMC, Wright-Patterson AFB. Capt. Simon will speak on "A Comprehensive View of Air Force Quality Control." In addition several members of the section will present "Highlights of the Ninth Midwest Quality Control Conference."

"FOR MANY ARE CALLED, BUT FEW ARE . . ."

INDIANAPOLIS The officers for Indianapolis Section's three, newly-established sub-sections are as follows:

CALENDAR OF MEETINGS -- NOVEMBER 20, 1954 -- DECEMBER 19, 1954

*Indicates meeting dates in November

SECTION	DATE	MEETING PLACE	TIME	SUBJECT	SPEAKER
Boston	9	———	———	Why Vendor Certification?	A. B. Mundel, Sonotone Corp.
Cincinnati	15	———	———	QC in the Electronics Industry	Leon Bass, General Electric Co.
Columbus	17	———	———	Recipe for Living	Chet Long, WBNS; Wilson Dumble, Ohio State Univ.
Dayton	9	National Cash Register Co.	8:00 p.m.	Fundamentals of Analysis of Variance	C. R. Hicks, Purdue University
Delaware	2	———	———	Management Controls	J. M. Juran, Management Consultant
Harrisburg	1	Caterpillar Tractor, York	———	Management Looks at QC	L. C. Ankerbrand, Caterpillar Tractor Co.
Huntsville	15	———	———	Practical Aids	W. E. Gibbons, Redstone Arsenal
Indianapolis	14	World War Memorial, East Rm.	4:00 p.m.	Quality Control in Action	W. A. MacCreahan, Bendix Radio
Kansas City	8	Metallurgical, Inc.	———	Plant Tour	F. Fitzgerald
Lansdale	9	———	———	What is Your Problem?	Panel
Los Angeles	1	———	———	Quality Control in the Factory	E. L. Fay, Deere & Co.
Michigan	10	Science Hall, Wayne Univ.	———	QC in an Automotive Parts Supplier Plant	Ralph C. Schulz, Ford Motor Co.
Milwaukee	6	Miller Brewing Co.	———	Panel Discussion on Quality Control	Milwaukee Section officers
Minnesota	1	Minneapolis-Honeywell Reg. Co.	———	Plant Tour	———
Montreal	9	———	———	Interpreting Control Chart Patterns	E. N. Beckett, Northern Electric Co., Ltd.
New Haven	7	———	———	Work Sampling	Prof. R. E. Heiland, Lehigh University
NE Indiana	9	C of C, Ft. Wayne	8:00 p.m.	Inspection by Optical Projection	Jack Stolp, Eastman Kodak Co.
Philadelphia	4	Germantown Cricket Club	7:30 p.m.	Annual Christmas Party	———
Rhode Island	16	———	———	Quality Control in Warping	L. I. Horner, Celanese Corp.
St. Louis	17	———	———	Statistics in Electronics Experimentation	Frank Caplan, Jr., General Electric Co.
San Diego	6	North Park Lions Club	6:15 p.m.	Using the Tools of Quality Control	E. L. Fay, Deere & Co.
Scranton-Wilkes-Barre	16	———	———	Statistical Methods in Management	W. H. Cook, Bureau of the Census
Seattle	14	Benjamin Franklin Hotel	7:30 p.m.	Measuring Association with Rank Valued Data	Joseph Livers, Boeing Airplane Co.
Southern Connecticut	8	Stratfield Hotel, Bridgeport	———	The Consumer Views Quality	Ephriam Freedman, Macy's Bur. of Standards, N.Y.
Southern Tier	7	Am. Leg. Clubhouse, Vestal	———	Designing Experiments for Ranking Means	R. E. Bechhofer, Cornell University
Syracuse	23*	———	———	SQC in the Foundry	Frank Winne, Oberdorfer Foundry
Toronto	8	Hamilton, Ont.	———	QC in Parts Manufacture	Julien Green, General Electric Co.
Trenton	3	Glendale Tavern	———	———	Dr. Gill, Rider College
W. Massachusetts	23*	Rovellis Rest., Springfield	6:00 p.m.	SQC Applications in the Chemical Industry	C. A. Bicking, Office Chief of Ordnance
Univ. of W. Ontario	1	Kitchener, Ont.	———	Some Methods of Quality Control	A. P. Deacon, QC Consultant
Wichita	7	———	———	Quality Control in Heavy Industry	James Barrabee, International Harvester
Winnebago	6	Manitowoc, Wis.	———	Gaining Uniformity with Statistical Quality Control	P. E. Dakin and E. Huber, Miller Brewing Co.
Worcester	9	———	———	Quality Mindedness	C. W. Carter, Rath & Strong, Inc.
Youngstown	8	———	———	Civilization Through Tools	C. G. Schelly, Wilkie Foundation

Bedford

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Vice chairman—A. P. Boblett, U. S. Naval Ammunition Depot
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Sec.-Treas.—J. Harding, Belden Mfg. Co.

"AS YE SOW . . ."

CLEVELAND This section is again planning to hold monthly quality control classes at both fundamental and advanced levels. The courses presented last year were very successful and therefore are being offered again this year.

DELAWARE The educational committee, headed by chairman H. C. Harris, E. I. duPont, plans to present a pre-meeting training session on four of the meeting dates during the 1954-55 season. These sessions will cover the fundamentals of SQC and details of application.

SOUTHERN CONNECTICUT The Southern Conneticut Section is planning to sponsor directly, quality control courses in Bridgeport, Waterbury, and Stamford beginning sometime in December, 1954. Education Chairman, John W. Judson, Electric Regulator Corp., Norwalk, has set up the tentative machinery of the program. Instructors for the courses are to be handpicked from the Southern Connecticut membership. Courses will run approximately twelve weeks, are fundamental in nature, designed for inspection personnel and production people who wish to acquire an understanding of statistical quality control principles. Emphasis will be on application rather than theory alone.

Following a discussion with the Southern Connecticut Section in August 1954, the Bridgeport Engineering Institute is offering a new course in Quality Control and Industrial Statistics at the college level, emphasizing the practical application of statistics for industrial quality control. The objective of the course is to provide local industrial supervisors and technically trained employees with background information and practice in the use of statistical quality control. Management aspects of quality control are included. The instructor, Charles W. Seaver, Underwood Corp., who is also a member of the section, was announced by Terrence A. Gilly, Dean of the Institute. The course will run 35 weeks.

UNIVERSITY OF NORTH CAROLINA The Institute of Statistics at North Carolina State College is sponsoring a nine-day intensive training program in Statistical Methods for Research Workers in Industry and the Physical Sciences starting Jan. 22, 1955 and running daily (including Sundays) through Jan. 30, 1955. The course is designed to make available to research workers in industry and the physical sciences the new and powerful statistical techniques of data analysis and experimental design. Guest lecturers will include W. J. Youden, National Bureau of Standards; Carl A. Bennett, Hanford Works, General Electric Co.; and Cuthbert Daniel, Statistical Consultant, New York City.

A registration fee of $100.00 will be charged and enrollment will be limited to the first 50 qualified applicants. For further information write to Institute of Statistics, North Carolina State College, Box 5457, Raleigh, N. C.

WICHITA For the first time, the Wichita Section will sponsor a training course of six units covering the principles of quality control. Competent instructors will be selected from the members of the section. Each unit will have a different instructor, or instructors. The course is scheduled to start in January.

SIGNIFICANT DIFFERENCES

Following the example of several other sections the Delaware Section is now issuing a monthly newsletter to all members. The section is also proud to announce that two of its members, O. P. Bruno and R. T. Trelfa, were recently elected to the grade of Fellow. Also Lewis R. De Prisco was recently appointed assistant purchasing agent at Atlas Powder Co., Wilmington.

— — — — —

Dr. Paul K. Ito, a student member of the St. Louis Section, has been awarded a post-doctorate fellowship at the University of North Carolina and is continuing his studies there on industrial statistics.

— — — — —

Seattle Section reports that the first member of its section to be honored by election to the grade of Fellow is Dr. G. I. Butterbaugh, University of Washington.

— — — — —

As a service to the membership and local industry the Southern Connecticut Section will provide circulation of employment information to the membership on a monthly basis. Individuals seeking employment or companies desiring quality control personnel may avail themselves of this service. The service is being handled by the Employment Information Service Committee under the chairmanship of M. G. Boyd, Jr.

— — — — —

Vincent Pellegrino, chairman of Trenton Section's Education Committee and instructor of the SQC courses at Rider College, has recently recovered from a rather serious major operation.

— — — — —

J. B. Bassett, past chairman of the University of Western Ontario Section and until recently quality manager at Timkin Roller Bearing Co., St. Thomas, Ont., has been appointed quality manager at Standard Tube and T.I. Ltd., Woodstock, Ont.

— — — — —

Washington Section is completing plans for a "Local Jackpot Night" on Mar. 23, 1955. The best papers on quality control by local talent will be presented at this meeting. The only requirement is that this be their initial professional presentation. All papers must be submitted to the secretary, Gilbert Maton, by Jan. 15.

The Western Massachusetts Section has scheduled the DoAll Company's traveling exhibit "Civilization Through Tools" for a meeting date late in May, 1955. Because of the cultural value of this exhibit, the section is also planning to make this its first social evening whereby the members may bring wives or girl friends.

— — — — —

Paul F. Heitz, treasurer of the Mid-Hudson Section, has recently been appointed quality control manager of IBM's new plant at Kingston, N. Y.

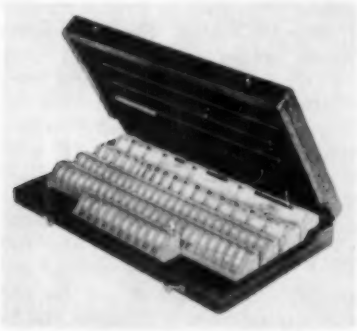
— — — — —

Wright Patterson AFB announces that Col. C. A. Peterson, Deputy Chief of Quality Control at Headquarters AMC for the past 15 months, has become chief of that office. He succeeds Col. C. F. Damberg, who has become chief of AMC's Aircraft Division.

What's New?

ROY A. WYLIE, *Editor*

News releases describing new products and literature should be sent to:
George R. Foster, Mng. Ed.
Room 6123 Plankinton Bldg.
161 W. Wisconsin Ave.
Milwaukee 3, Wis.



Webber Gage Company, 12899 Triskett Road, Cleveland 11, Ohio, announces a new set of "Laboratory Master" Gage Blocks, said to be the nearest approach to absolute dimensional perfection ever attained. Blocks are certified accurate within plus or minus one millionth of an inch. Chrome carbide, an extremely hard, durable, fine-grained material is used in their manufacture in order that the blocks will not oxidize, corrode, or form microscopic films. Every "Laboratory Master" block is checked for accuracy in a constant temperature of 68 degrees against master blocks which are regularly checked by the new Zeiss Opton Interferometer, which uses the wavelength of light as its standard of measurement. Each set of 82 blocks is guaranteed to the following accuracy:

Parallelism—across width	.000001"
along length	.000001"
Flatness—across width	.000001"
across length	.000001"
Deviation from marked size	±.000002"
Calibration by interferometry	±.0000002"
Accuracy of calibration	±.0000008"
Coefficient of expansion, per 1° F. per inch	4×10^{-6}

Surface finish—by optical comparison, equal to a quartz flat

Corrosion resistance—approximately ten times that of 18-8 stainless steel

★ ★ ★

Large screen precision oscilloscopes are a new product development announced by **Electromec, Inc.,** Oscilloscope Department, 3200 North San Fernando Blvd., Burbank, Cal. Units are available in 21" and 17" rectangular tubes, for data plotting, production tests, wave form analysis, education and display uses. Among the important features of the new oscilloscopes are high resolution, ±1° linearity, stable DC amplifiers, calibrated time base (from 10 μ sec/inch to 1 sec/inch), gain controls calibrated in peak-to-peak volts/inch (10mv peak-to-peak or 1 mv peak-to-peak sensitivity), low rate of drift and excellent long term stability. Performance is not affected by line voltage changes from 105-125V.

★ ★ ★

A new Internal Groove Diameter Gage has been introduced by **A. G. Davis Gage and Engineering Co.,** 21435 Dequindre, Hazel Park, Mich.

The gage was developed to satisfy the requirements of a production gage for use either at the machine or in final inspection. The design eliminates many of the delicate, easily-broken details of former groove gages, and will repeat to tenths under the most adverse conditions. The gage is supplied for standard "O" ring and snap ring grooves with bores from 0.480" to 4.750" diameter.

★ ★ ★

Angle Computer Company, Inc., 1709 Standard Avenue, Glendale 1, Cal. has now available five models of their Studler Compound Angle Computer. It is accurate to one minute of the arc in each of three planes. The Angle Computer is a highly versatile measuring device for surveying the angles of precision machined parts, casting and die work. It usually reduces inspection time considerably over the customary methods of angle inspection, and is easily taught to inexperienced workers. Three axes of rotation—horizontal, vertical and radial—are incorporated. All protractors are graduated from 0 to 90 degrees in four sections of the circle. The horizontal protractor is equipped with two verniers set at 90 degrees apart so that a reading can be taken in any position. The vertical and radial protractors have one vernier each. All verniers are furnished in one-minute graduations as standard equipment.

★ ★ ★

New Standard Division, U. S. Expansion Bolt Company, York, Pa., has introduced a new, direct-reading hole gage to measure the internal diameter of small holes ranging from 0.020" to 0.130" with an accuracy of

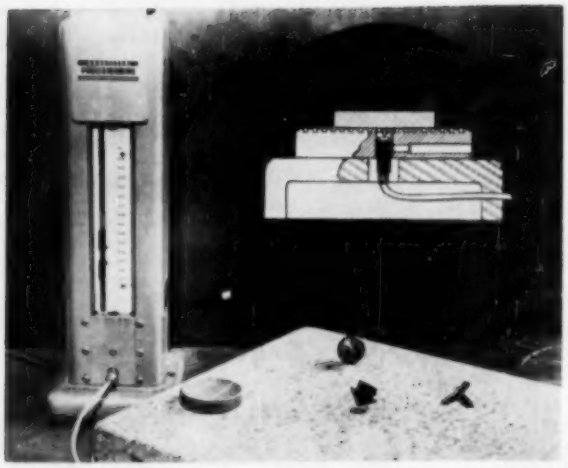
0.0005″ over the entire range. The new instrument is called "KWIK-CHEK" and is similar in appearance and operation to a ball-point pen or automatic pencil. The gage makes possible rapid precision measurements using one hand, leaving the other hand free to hold the work being checked or to perform other operations. The scale is graduated in thousandths of an inch and has a built-in magnifier to enable the user to obtain readings to the nearest half-thousandth.

★ ★ ★

Federal Products Corporation, 1144 Eddy Street, Providence 1, R. I., is now producing a long-range dial indicator that will measure two full inches in increments of 0.001″. The indicator is furnished in the "D" size (2¾″ dia.) to American Gage Design Committee specifications except for the length of the stem, the dust cap and the rack. There are two revolution counters to enable the user to keep track of the hands so that he always knows which revolution of each hand is being read. The pullback spring is enclosed in the case, making possible the use of the indicator in vertical or horizontal position. The complete line of Federal Indicator backs and points is available. All of the basic features of the regular line of Federal Full-Jeweled Dial Indicators are incorporated in the new long-range model.

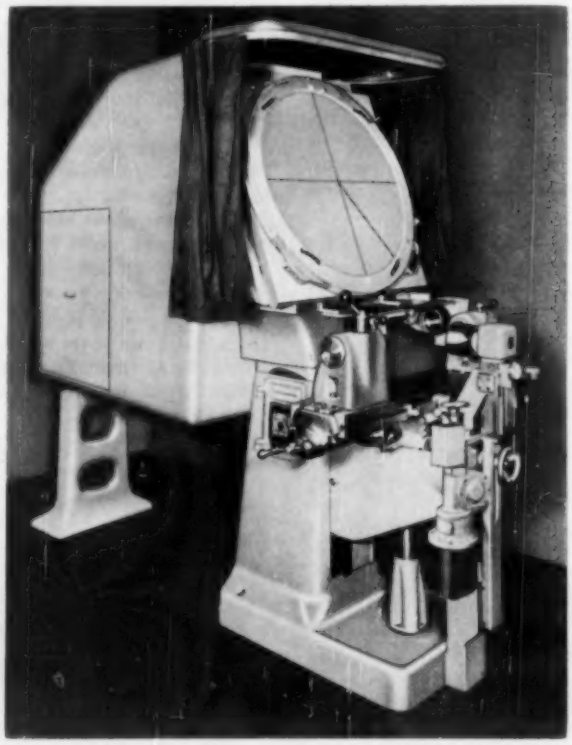
★ ★ ★

Plunjet Steel or Stone Flatness Gages,manufactured by the Sheffield Corporation, Dayton 1, Ohio,



are designed for checking surface flatness and surface irregularities to a high degree of accuracy. The gaging element is a Plunjet gaging cartridge mounted in a steel or stone surface plate so that the contact point of the Plunjet projects above the surface of the plate. Amplification is 2000 to one. Workpieces are presented to the surface plate and passed over the contact point of the Plunjet gaging cartridge. Variations from flat are indicated by the position of the float in the Precisionaire. No special skills, "know-how" or calculations are required to operate this gage. The standard steel flatness gage has a 4⅞″ by 6″ serrated surface plate with an overall flatness of fifty millionths. Standard stone flatness gages are made of pink granite, four inches thick, and have a flatness overall of fifty millionths. They are available in four standard sizes, 8″ by 12″ and 12″ by 12″ with two ledges, and 12″ by 18″ and 18″ by 18″ with four ledges. The gages are normally supplied with 0.0025″ reverse Plunjet; however, the full range of Plunjets can be utilized and special flatness gages of any size and with any number of Plunjets can be supplied.

★ ★ ★



A new portable, self-contained, electronic test device for vibration and shock analysis has been marketed by the **York Division** of the **Bendix Aviation Corporation,** York, Pa. Designated "Flash-lok," the unit eliminates the time-consuming adjustments required of former methods to synchronize the speed of light flashes with the vibration of the object being tested. Excitation for the "Flash-lok" is derived directly from electrically driven vibration equipment, or from an accelerometer attached to mechanical equipment. The light may be made to flash at a rate differing from the vibrating base by one cycle or five cycles. This allows detailed study and analysis by slow motion, or general detection of resonances by fast motion. The light flashes may be locked exactly to the vibration frequency when desired. Operating frequency is 30-2000 cps. One 1D21 flash lamp, reflector and connecting cord are standard equipment, with space provided in the instrument cabinet for storage of the lamp when not in use. A second 1D21 lamp may be connected if needed, and a jack is provided for connection of commercially available white light sources when extra illumination is required. Operation is from 115 vac power source, weight is less than 21 pounds, and size is 9½" by 8¼" by 12½".

★ ★ ★

The Jones and Lamson Machine Company, Springfield, Vt., recently announced a special 30-inch screen optical comparator for inspecting very heavy parts. The comparator is built to machine tool standards with a milling machine type base and table. Clearance for loading and unloading by crane is provided. A maximum of 12" in diameter and 20" in length may be held between centers on 42" table. Horizontal measurement is 16" and vertical measurement is 6". Electrically controlled power elevation is added to increase ease of operation. Standard projection lenses from 10 to 100 magnifications are used as needed. Reflection attachment and coordinate slide tracing attachments are available.

New Literature

The following new literature is available by writing direct to the companies listed:

Discovery Sampling Inspection, the well-publicized development of Lockheed Aircraft Corporation, Burbank, Cal., is presented in an il-

Unscrambles Metal Mixups

THE CYCLOGRAPH. This instrument permits truly high speed, nondestructive sorting of raw, semi-finished or finished parts by their metallurgical characteristics. With the new Automatic Sorter Unit speeds up to 300 pieces per minute are possible with the use of suitable feeding equipment. Used by leading industrial firms everywhere.

J. W. DICE CO., Englewood 8, New Jersey

Non-destructive Testing and Measuring Instruments

***How to speed production with* MAGNIFIERS**

New! Illuminated 10X Pocket Magnifier

WRITE for new handbook and catalog, "Industrial Magnifiers—How to Choose and Use Them." Bausch & Lomb Optical Company, 50235 Bausch St., Rochester 2, N. Y.

Cut waste, get faster, surer inspection by fitting the magnifier to the job. This new Bausch & Lomb Illuminated Coddington floods entire viewing field with bright light *through* the lens, permitting quick, accurate, ON-THE-SPOT inspection, without need for outside lighting. Image quality is excellent! Carry this new magnifier with you always—anywhere..$7.50

Another product by Bausch & Lomb—recognized world leader in all things optical.

BAUSCH & LOMB *Magnifiers*

lustrated 13-page pamphlet prepared by the Director of Quality Control. *Pre-Control* method of controlling quality at the machine is described in a publication available from Jones and Lamson Machine Co., Springfield, Vt.

Laboratory Report #11, the first of three articles on System Analysis with the Complex Plane Analyzer, is available from Technology Instrument Corporation, 531 Main Street, Acton, Mass.

Barber-Colman Company, Rockford, Ill., has issued a new bulletin on the "Impressor," a portable hardness tester for aluminum, soft metals and plastics.

TRI-ROLL Thread Comparators is the subject of a new bulletin issued by Pratt and Whitney, West Hartford 1, Conn.

Bulletin 541, published by Industrial Engineering Corp., 2720 Vine St., Cincinnati 19, Ohio, describes their standard products, Gage Gard and Viz-O-Line test stands and instrument panels.

Model "53" Airflow Precisionaire is the title of a 30-page catalog and price list published by The Sheffield Corp., Dayton 1, Ohio. The full line of instruments, components, accessories, spindles, air snaps, and special gages is described and illustrated.

Allied Radio Corporation, 100 N. Western Ave., Chicago 80, Ill., will supply without charge their 1955 catalog of electronic equipment, including equipment for industrial maintenance, research, and production.

Beginning with the next issue, January 1955, You will receive

Industrial QUALITY CONTROL

Every Month

POSITIONS WANTED

Address all replies to box number references to: American Society for Quality Control Room 563, 50 Church Street, New York 7, N. Y.

YOU NEED THIS QUALITY CONTROL ENGINEER, if you're located in the New York, New Jersey Area. Degree in statistics, veteran, married. Background in cigarette quality control and large scale acceptance sampling. Has set up quality control program in large mail order firm. Desires change from mail order to industrial type operation. Please reply to Box 11C1 at the above address.

QUALITY CONTROL SUPERVISOR with sixteen years experience in the manufacture of automobiles desires position with progressive firm. Willing to locate in another country if necessary. Thoroughly versed in welding, soldering, metal-finish, paint, trim, hardware, etc. Please reply to Box 11C2 at the above address.

QUALITY CONTROL TRAINEE, age 23, four years experience as a statistician. Possess a B.B.A. degree in statistics and expect a M.B.A. degree this semester. Desire a position that has opportunity for advancement and salary is not too important. Will relocate. Please reply to Box 11C3 at the above address.

QUALITY CONTROL ENGINEER AND STATISTICIAN. Three and one-half years of experience in quality control and application of statistics to industrial problems. Have set up and managed quality control systems which included: quality records, forms and reports; all types of sampling plans and control charts; analyzed process capabilities; analyzed sources of poor quality and made recommendations. Organized gaging policy and purchased gages and test equipment; wrote instructions for both inspectors and operators to test equipment to be used, etc. M.A. degree in mathematical statistics. Member ASQC. Will relocate. Reply to box 11C4 at the above address.

QUALITY CONTROL MANAGER desires new position with a progressive manufacturing company. Senior member of ASQC for eight years and charter member and officer of section. Engaged in quality control since 1943 and presently located in midwest. Please reply to Box 11C5 at above address.

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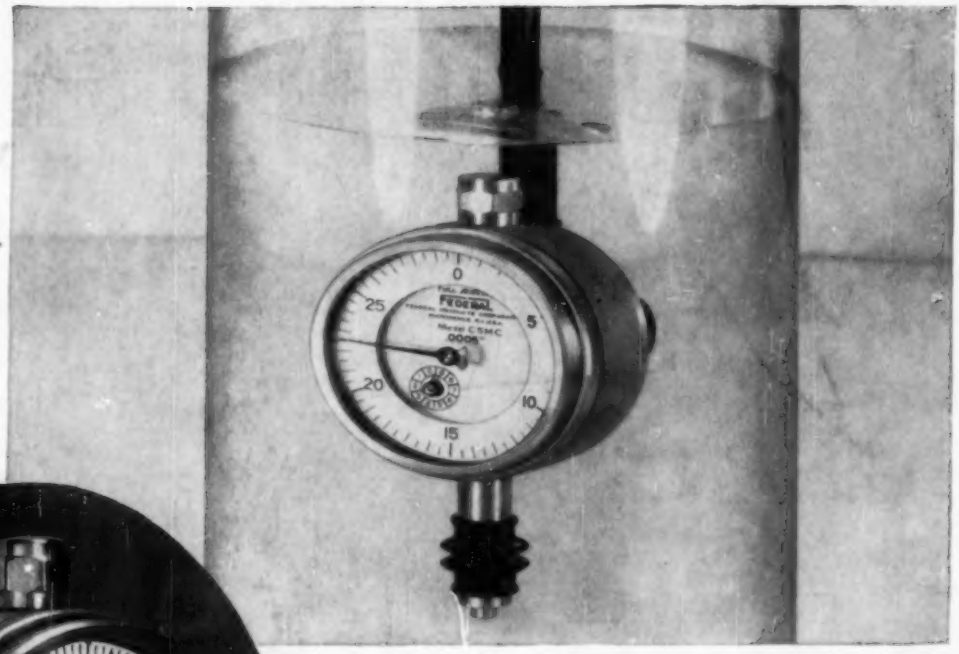

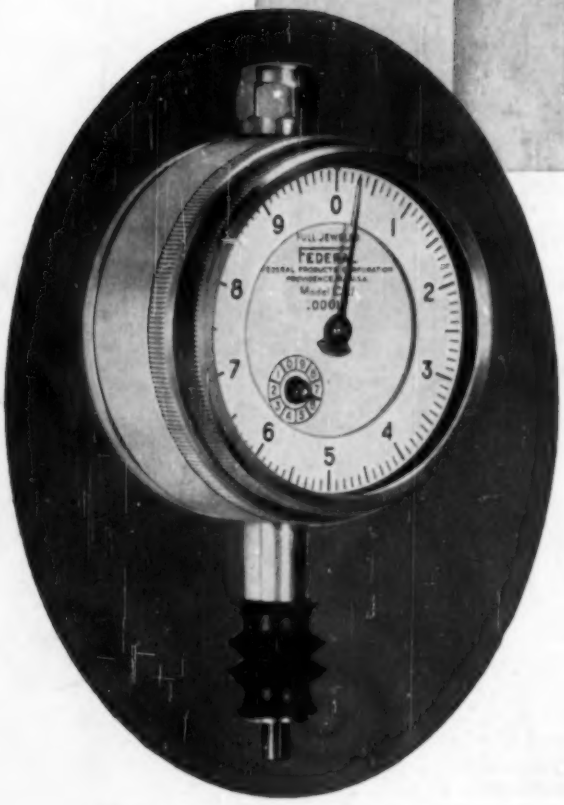

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